



Drivers and limits for transport

Report 9

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Total number of authors:
15

Publication date:
2014

Document Version
Publisher's PDF, also known as Version of record

[Link back to DTU Orbit](#)

Citation (APA):
Kristensen, N. B., Nielsen, T. A. S., Gudmundsson, H., Meza, M. J. F., Haustein, S., Møller, M., Christensen, L., Knudsen, M. A., Pons Rotger, G. A., Grunfelder, J., Mulalic, I., Pilegaard, N., Madsen, E., Abate, M. A., & Kveiborg, O. (2014). *Drivers and limits for transport: Report 9*. DTU Transport.

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Drivers and limits for transport

Results from research into socio-demographic factors, long distance travel, land use and urban form, determinants of capacity utilization in freight, and the policy implications of research based knowledge



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April, 2014

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Cover photo: DTU Transport

Published by: Department of Transport, Bygningstorvet 116B, 2800 Kgs. Lyngby, Denmark

Request report: www.transport.dtu.dk

ISSN: 1601-9458 (electronic version)

ISBN: 978-87-7327-261-9 (electronic version)

ISSN: 1600-9592 (printed version)

ISBN: 978-87-7327-262-6 (printed version)

Preface

This report summarizes key outcomes of the study 'Drivers and Limits' that was supported for the period 2009-2013 by a research grant from the Danish Strategic Research Council. The project investigated - for the empirical context of Denmark - key driving forces behind transport growth, as well as the notion of limits to mobility, arising out of system interactions or set by external policy ambitions.

The report is divided into three main sections. The introduction Part I details the study motivation and its background. Part II summarizes the results obtained within the four areas of research and sub-themes developed during the course of this study, namely,

- Travel patterns among young and elderly population groups
- Long Distance Travel, including international travel
- The role of land use, urban form, and infrastructure for travel demand, and
- The impacts of capacity utilization in road freight transport

Part III considers possible policy implications of the results. The conclusion Part IV points to areas of future research interest that emerged in light of the integration of analysis results from the study.

In addition to this report a large number of scientific articles and conference presentations with more detailed findings have been published from the project.

I hope the report will provide a useful overview and inspire fellow researchers and policy makers at home and abroad to consult the specific results.

Niels Buus Kristensen and Thomas Sick Nielsen,
Project managers of the Drivers and Limits study.

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PART I: Introduction

I.1 Motivation

Mobility has a fundamental value to society. It enhances business competitiveness, facilitates connections to good jobs and services, creates possibilities for individuals and families to travel long distances, visit relatives, and have access to products, goods and worldwide destinations. Mobility of people and goods strengthens the opportunities that help a country like Denmark to remain competitive and well integrated to the world economy. The increase in volumes of passenger and goods transport on national roads - before and after the recent economic recession - can to some extent be seen as positive indicators of society's advances in prosperity, economic activity and welfare.

However, growing economic vitality also creates road capacity problems and undesirable levels of traffic volumes in particular during peak hours. Bottlenecks and traffic congestion are costly to society and can quickly erode the advantages and efficiency of movement that urban mobility can offer. Growing road traffic can impose direct costs on other users through congestion and accidents but also on non-transport users in the form of deteriorating air quality, noise and loss of amenity that negatively impact quality of life, social and economic welfare.

Moreover, with the raising awareness of climate change both domestically and internationally transport growth has become an issue of more general policy concern (ITF 2008; Trafikministeriet 1999; Teknologirådet 2012). The role of transport in long term strategies to avoid dangerous human interference with the global climate is increasingly addressed in research and policy making.

Regionally, the European Commission's Transport Policy White Paper emphasizes that the paramount goal of European transport policy is "to help establish a system that underpins European economic progress, enhances competitiveness and offers high quality mobility services while using resources more efficiently" (European Commission, 2011). Specific goals and strategies for transport GHG emissions have been proposed.

In Denmark the Parliament and Government in 2009 agreed on a green transport vision that is to ensure a high level of mobility, with reduced pollution and negative impacts of transport (Transportministeriet, 2009). The government has not defined specific GHG emission goals for transport, but significant reductions in overall emissions reduction have been agreed (Danish Government 2013).

Better understanding of the tendency towards growth for passenger and freight transport is a key issue for the development and implementation of such strategies. What will drive transport to grow when the recession is over, and where could it be met by limits? Which aspects of mobility could be stimulated without inducing further negative impacts, and how could transport growth be influenced to reduce negative impacts and secure the climate without undermining the benefits of mobility? Are policy interventions to weaken the drivers behind transport growth necessary and possible, or would such efforts lead to undesirable 'curbing of mobility', as it has been put by the European Commission (2011).

The motivation for the Drivers and Limits study has been to gain a deeper understanding of some of the most important factors that influence (drive or limit) the demand for passenger and freight transport in the context of strategies to promote mobility while minimizing impacts such as congestion and climate change.

The study has first of all been based on general insights and questions arising from existing research into transport demand and growth as briefly summarized in the following. Following this, the key concepts and research topics of for the study will be outlined.

I.2 Understanding travel demand

The demand for transport has a multidimensional constitution that can be understood through a variety of scholarly approaches. The dimensions of transport demand include not only the transport volume per se, but also component factors such as trip frequency, travel distance, modal split, and capacity utilization of vehicles and infrastructure; these are sometimes studied one by one, sometimes jointly, within or across scholarly disciplines of economics, geography, sociology, and psychology.

In the transport economics literature travel is basically conceived as a derived demand, undertaken for a variety of purposes rather than for its own sake (Small and Verhoef, 2007). Accordingly, travel demand is seen as driven by factors such as the economic activity in various transport demanding sectors, the income levels of transport consumers, the price of transport relative to other services, the value of time, and consumer preferences (Goodwin, P., Dargay, J., Hanly, 2004).

Since transport takes place in concrete settings contextually defined by the interaction of the built up environment and specific geographic configurations, the transportation and land use literature offers a complementary explanation for how drivers affect travel demand. Individuals are often assumed to operate under relatively “fixed time and money budgets” for travel (Zahavi and Talvitie, 1980). Under such conditions, the built environment, and the density of the population and its travel destinations affect the distances covered by journeys, and the modal split, in particular the share of public transportation services (Schäfer, 1998).

Hence, the combined influence exerted by geographic conditions, spatial development characteristics (such as density) and available transport technology and infrastructure is assumed to determine the levels of connectivity for a given place and thereby influence how people travel, in terms of frequency, distance and mode; These conditions can in turn can emerge into limits for the viability of suitable alternatives to the car (Giuliano and Dargay, 2006; Næss, 2006a; Ech-enique et al., 2012).

Another dimension is addressed by the transport behavioural literature which places focus in socio-demographic factors such as the life stage and the specifics dictated by age, gender, and individual notions of well-being e.g., in families with children, or amongst older population groups (Rosenbloom, 2006). The behavioural literature further explains how travel demand is affected by preferences linked to habituations and socialization (Steg, 2005), and how it may differ according to travel purposes such as commuting, leisure and shopping. Statistical and sociological perspectives are generally converging to show that at high levels of socio-economic

development and preferences for travel to long distance destinations by use of faster modes (air, high speed rails) has become prevailing features among populations in industrialised countries (Gössling et al., 2009).

In sum, existing research has posited that a number of economic, spatial and socio-demographic factors are likely to influence and condition the demand for transport. 'Transport demand' is not seen as a singularity but may refer to travel for different reasons (activities, purposes) and may become manifest in aspects such as trip frequencies, travel distances, modal shares, capacity utilization, traffic volumes, and speed, to name a few.

The factors and dynamics identified in each research approach do not necessarily exclude one another; rather the factors will jointly influence the different aspects of transport activity in a complex way over different spans of time, depending on the spatial and socio-economic context.

This complexity obviously presents policy and planning aiming to address transport demand with significant challenges.

I.3 Policy issues - growth, decoupling and 'peak travel'.

I.3.1 Transport and Economic Growth

The questions about what constitute drivers for and limits to the demand for transport, and how to possibly incorporate these elements in policy making has been studied from various angles, without reaching general uniform conclusions. While especially the close relationship between transport and economic development has often been confirmed (see also figure I.1), it has been more challenging to determine clear policy implications; should the increasing demand for example be accommodated to support economic growth, or could it be constrained to reduce the negative environmental impacts without hampering the economic development (Ecola and Wachs 2012).

Particular attention has been given to explore the links between investments in infrastructure (building new roads, bridges, airports) and the ensuing levels of operations and economic activity in urban agglomerations (Fujita et al., 1999) (Krugman and Venables, 1995). That good transport infrastructure in general is vital for regional development is not much disputed; however it has proven to be challenging to determine under which circumstances already developed areas can generate additional growth in this way, or lose it without continued investments; more research has been called for.

More recently the effects of globalization and the displacement of economic activity to farther away destinations have been recognized as a significant economic driving force for transport activity and vice versa (Corbett and Winebrake, 2008). The same is the case for global tourism, a major component in the recent surge in international aviation, also with potentially serious implications for the environment (OECD 2010).

I.3.2 Transport, environment and 'decoupling'

Over the last two decades or so the environmental agenda has become a significant element in the study of drivers and limits of transport demand policy. The environmental pressures created by transport are diverse where the attention to them has shifted over time. An early concern was the emergence of critical pollution issues in cities (Flyger et al 1976, Mage and Zali, 1992), later also encompassing energy consumption and oil dependence (Schipper et al., 1992), which has expanded to consider the role of transport in sustainable development more broadly (Banister, 2000; OECD, 2000), and most recently the urgency of climate change (Stern et al., 2006; Kahn Ribeiro S, et al., 2007).

To help overcome the apparent dilemma especially between exploiting benefits of increasing mobility and suffering the impacts of climate change, two different approaches have been pursued:

- One approach has been is to explore the potential for introducing alternatives to petrol and other fossil fuels as energy carriers (e.g. biofuels, electricity, hydrogen etc.), leading to a diverse number of predictions and recommendations with regard to policy (Ogden et al. 2004; Azar et al. 2003)
- Another approach, more pertinent to the Drivers and Limits work, has been to look for options to break or open the strong link between economic and traffic growth, a process phrased in the literature as “decoupling”.

A pioneering research effort into decoupling was advanced by the Organization for Economic Cooperation and Development from 2003 onwards. Among the conclusions were that nations that are able to decouple their economic development patterns from equivalent increases in physical transport flows could face an easier path a future low carbon transport system (OECD, 2006a). Based on comprehensive surveys of European experts Tight et al (2004) identified general policy measures, such as road pricing and controlled parking zones that could likely be applied to promote decoupling without large detrimental effects of economic growth.

I. 3.3 Transport and 'peak travel'

However, whether decoupling could and should in fact be pursued through policy actions, remains much debated (Goodwin 2013). Decreasing per capita car use trends observed in several industrialized nations, may for example suggest a diminishing need for this.

Some researchers name this trend “peak car use” as they see a trend as indicating a shift from steady growth to a future where car use will be in decline (Millard-Ball and Schipper, 2011; Newman and Kenworthy, 2011). In other academic works the evidence is considered indicative of a slowdown to the historic gradual growing trends of distance travelled per car per person and they see that saturation, rather than peaks followed by decline is what the data illustrates (Bureau of Infrastructure, 2012). One point of agreement is that the data for this trend pre-dates the recent years of world economic and financial downturns and, in some countries, it can be traced back ten or even twenty years (Metz, 2010; Goodwin and Van Dender, 2013; Sivak, 2013).

In Denmark the trends over the last decades have also demonstrated slowing growth in the number of passenger-kilometre travelled by car per person (Statistics Denmark, 2012). Denmark may have experienced a peak followed by a decrease in vehicle travel since 2007. However, this is paralleled by decreasing GDP and episodes of economic recession, making it harder to discern clear implications. Understanding more about the factors behind these trends is therefore highly relevant also for Denmark.

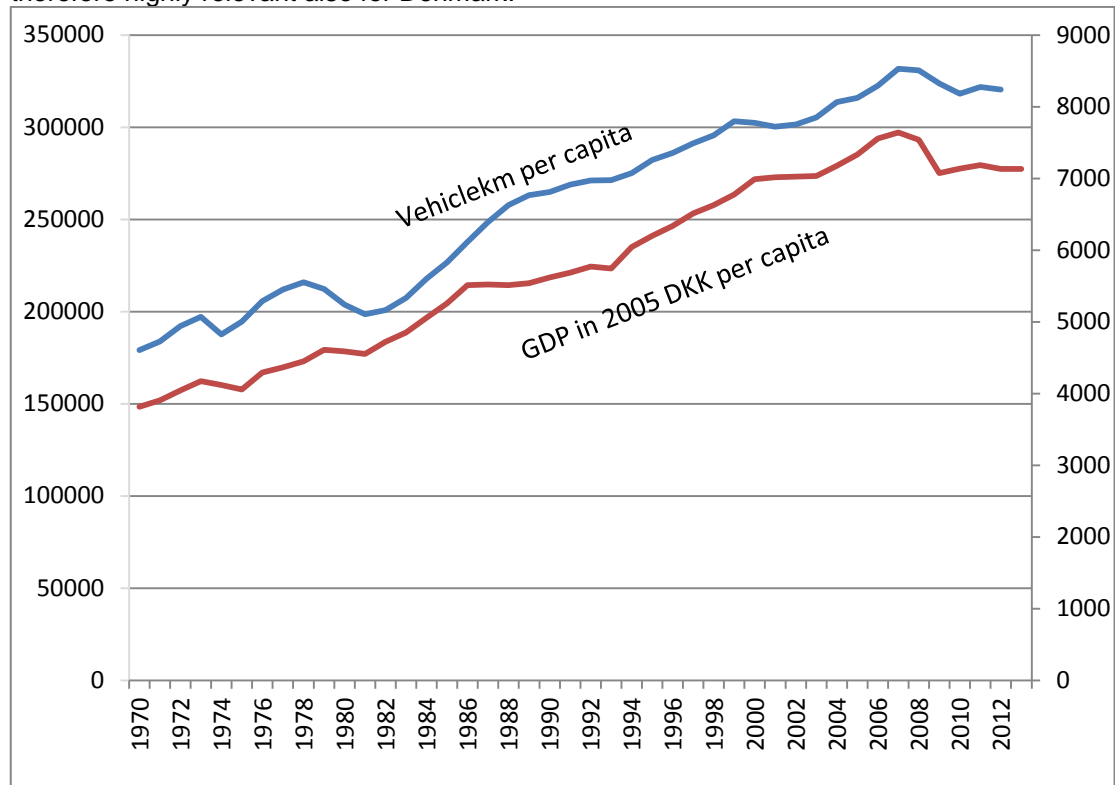


Figure I.1. Vehicle km on Danish roads (*Nationalt trafikarbejde*) per capita (right axis) and GDP in 2005 DKK per capita (left axis) 1970-2013.

I.4 'Drivers' identified in previous research

The notion of 'drivers' behind transport growth and their possible susceptibility to limits and policy interventions has been explored in a number of broad international and Danish studies and policy analyses, many of which have been triggered by similar concerns over climate change, oil dependence, and congestion impacts as noted above. Significant international examples include Van Dender and Clever (2013), EEA (2012); EEA (2008b); Åkerman and Höjer, (2006); van der Waard et al., (2013) and Hickman and Banister, (2007), while Danish studies in the area include for example Teknologirådet (2013), Infrastrukturkommissionen (2007); and Clausen et al. (2002).

This summary will not provide a detailed review of these studies but will briefly highlight two reports, one European and one Danish, which have contributed to inspire the broad approach of the Drivers and Limits study, along with the more specific issues raised within the individual transport research disciplines as will be presented in the following sections and Part II.

A unique study conducted by the Danish Road Administration (Clausen et al 2002), set out to characterize the 'anatomy' of growth in road passenger transport, through an open interdisciplinary literature review. The review identified 23 different determinants (drivers), classified into four categories,

- Economic (8 drivers),
- Sociological (5 drivers),
- Political-institutional (6 drivers) and
- Planning and structural (4 drivers)

Included are well known economic transport drivers such as income growth and prices of vehicles and fuels, as well as less frequently addressed ones such as 'hectic pace' of modern family life, and the 'historic' disposition of road authorities to promote a free vehicle flow. The study did not seek to quantify any of the factors and it did not address issues such as globalization, environmental concerns, or freight transport.

One policy relevant conclusion is that several drivers seem to be located outside of the transport authorities' normal influence domain (corresponding to the 'derived' nature of demand according to transport economics). Another conclusion was that the inter-disciplinary approach to the identification of drivers had proven valuable for stimulating debate and engaging policy makers (Clausen et al 2002, p 63).

Another study called "Beyond Transport Policy" conducted by the European Environment Agency (EEA 2008b) complements the Danish report. The focus was exactly on drivers of transport demand existing 'beyond' the transport system itself, with the aim to identify potential national and European level policy actions to reduce GHG emissions. The study zoomed in on three selected case areas within freight and passenger demand, namely,

- Effects of food production and consumption on shopping journeys and freight,
- Short-haul air travel for business and leisure travel; and
- Effects of 'education based' travel on transport demand

In each case the study looked at how the existing literature addressed potential drivers behind transport demand (understood as distance, volume and modal shares). The following six categories of drivers were explored,

- Socio-demographic changes,
- Economic growth and globalisation,
- Physical changes to urban form/land use,
- Organisational changes at workplaces and schools,
- Socio-cultural changes, and
- Technological developments

Hence the study went beyond the Danish analysis not by only identifying more and different types of drivers, but also by analysing in a qualitative way how these drivers were seen to operate and interact within each of the three specific fields.

The study suggests that generally 'strong links' exist between the factors operating within the selected sectors and transport demand (EEA 2008b, p. 63). However, the study did not lead to significant generalizable results in terms of universal drivers of transport demand or common policy recommendations. The study rather highlights the complex and differentiated ways in which external factors and sectors are likely to affect transport demand. The study further pointed to knowledge gaps and called for more research on the transport consequences of 'non-transport' decisions (EEA 2008b, p. 9).

The summary perspective drawn from these studies is that it seems highly relevant to apply a multi-disciplinary approach to the study of transport drivers and associated limits, since the mechanisms behind transport demand are complex and diverse and the different approaches can supplement each other. Moreover it seems less advisable to seek a universal explanatory model with associated general policy implications across all areas of transport demand; but more fruitful to study different areas with more specific research questions and methodologies within a common framework, in order to produce results with potentially more targeted policy implications..

I.5 Framework for Drivers and Limits in the present study

Departing from notions of transport demand and its drivers and limits, as summarised in sections I.2.-1.4 the present study opted to zoom in on specific areas where important transport drivers and limits could be studied in some detail exploring existing and developing new data sets connecting transport activity to underlying factors.

The expectation was that knowledge could then begin to be positioned in the form of bridges from a bottom-up perspective and across diverse disciplinary mobility research areas (e.g., transport economics, logistics, land use-transport interaction, behavioural psychology, policy analysis) to attain a form of more complete understanding of drivers and limits to travel demand, without seeking a universal synthesis.

With this goal in mind a framework was outlined at the beginning of this study to help structure the research as is illustrated in Figure I.2. According to this notion, the total demand for passenger and freight transport is determined by the level of demand for goods and services the society requires according to activities in each sector. The project focussed on four key societal forces ('driver' areas) that are assumed to shape the way in which economic growth impinge on demand and eventually transport, considered in dimensions such as distance, volume, and means of transport.

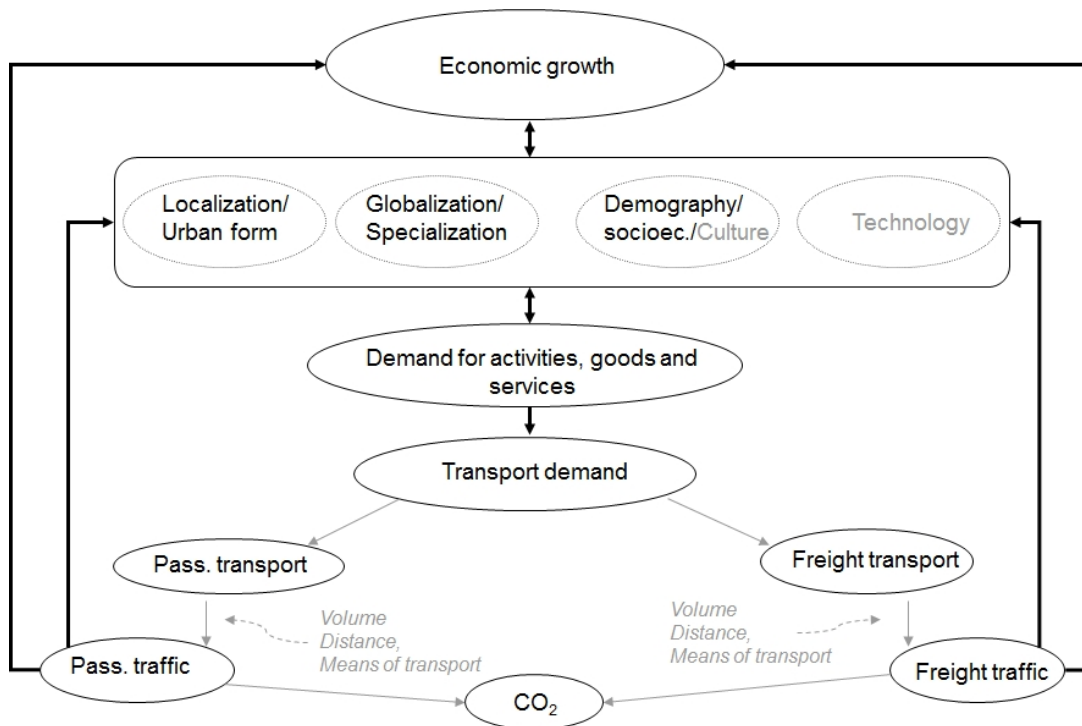


Figure I.2: Figure representing the approach of the present study. Factors not looked at are indicated by grey.

Two of the factors are integral to the economy and growth; they are *globalization* leading to increasing long distance passenger and freight travel (Corberdt and Winebrake, 2008), and *urban structure*, because the spatial separation of activities affects the economy and travel by creating variable land rents that affect location and economic competition and daily personal travel and transport (Næss, 2006a). Two other factors are external to the economy; *technological developments* and the grouped elements of *demography- socio-economic-cultural factors*.

The demand for transport leads to physical traffic flows, which again can lead to environmental impacts. In the figure emissions of CO₂ represent negative outcomes, that together with congestion and other impacts could lead to limits for mobility, either internally (congestion) or externally (via policy measures or even public resistance).

As indicated in the figure this study does not address technology topics. Not because they are irrelevant for the understanding of the transport system or the policy issues, but because the study is limited to the demand side of transport and several other studies have looked into for example energy efficiency, alternative fuels and infrastructure solutions (see e.g. Klimakommisjonen 2010). Similarly, the “supply side” component of the transport system, including the level of service provision will not be considered. However, the role of technology is addressed indirectly e.g. as an attribute affecting capacity utilization in freight transport (truck size, see chapter II.4) and in regard to transport infrastructure provision for commuting (Copenhagen Metro, See chapter II.3).

Lastly as for drivers, “culture” as a factor that appears in Figure I.2 is only tangentially addressed as they contribute to shaping the travel preferences of the youth and the travel preferences for the older population (chapter II.1).

I.6 Drivers as addressed in the study

‘Drivers’ are understood as factors or broad sets of factors that drive and stimulate some aspects of transport demand such as trip frequencies, distances travelled, and overall volume. The drivers addressed in the study report have been selected based on their likely significance and their general policy relevance. They are more specifically grouped in the following four areas of research that will be briefly introduced below,

- Demographic and socio-economic factors: Travel patterns of young and elderly
- Globalization and Long distance passenger travel
- Land use, urban form and Transport
- Road freight transport and capacity utilization

I.6.1 Demographic and socio economic factors: Travel of young and elderly

Socio-economic aspects are key to understand individual, household and population travel behaviour. Demographic variables can explain many changes and fluctuations of the national transport demand. Similarly, social and cultural differences and traditional ways of using transport affect the total national profile of mobility and transport. It is therefore necessary to be aware of the quality and quantity of such changes in order to strengthen the capacities to anticipate and predict future transport trends (Siu et al. 1995).

In Denmark, as well as in many other western countries, challenges are expected with the ageing of the post war baby-boom generation and their influence on the total transport demand (Rosenbloom, 2001; OECD, 2000). The coming young generations may also adopt behaviour that differs compared to former generations with regard to for example car use, and thereby potentially change projections of the demand of future populations (Lyons et al., 2002).

I.6.2 Globalization and Long distance passenger travel:

At the individual level, rising incomes, increasing leisure time, and earlier retirement are making it possible for people to spend more time on leisure trips (Mokhtarian and Salomon, 2001). Time and income availability coupled with sharply falling costs of long distance transport, due to e.g. liberalisation and increased competition in air and other transport services has created a bust on long distance travel particularly in industrialized countries (Gössling et al., 2009).

A greater proportion of studies on passenger transport is concentrated in exploring short distance travel, allowing to reach conclusions on regularities such as that people operate under fixed budgets of money and time for travel (Zahavi and Talvitie, 1980; Schäfer, 1998). Less is known about factors that drive and explain long distance travel. Long distance travel accounts for a significant and increasing part of passengers and freight transport and increasingly contributes to the negative externalities associated with transport (Environment Agency, 2008).

I.6.3 Land use, urban form, and Transport

Research about the importance of urban structure for transport in Denmark and Europe has shown that residential location and the characteristics of the built environment are important drivers affecting the distances travelled and total transport demand growth (Nielsen, 2002, Næss, 2006a; Echenique et al., 2012). Scholarly literature findings indicate that urban form and public transit supply affect travel demand (Bento et. al. 2005, Guiliano and Dargay 2006). Increased density and provision of high quality public transport has the potential to reduce car traffic and CO₂ emissions by contributing to reducing total travel needs and changing modal split. Therefore, the integration of land use planning and transport in coordinated processes might have significance to minimizing the problems associated with the growth of traffic and future transport growth. The relationship between urban structure and travel is found in the topical literature to be permanently changing, this accordingly suggest the existence of a reduced distance decay; and also suggest that the effect of localisation of workplaces can be ambiguous (Christensen & Fosgerau, 2002). Finally, as the physical mobility of labour and workplaces is important for the productivity and economic growth, these questions cannot be answered trivially (NTS, 2009).

I.6.4 Road freight transport and capacity utilization

The potential of exploiting economies of scale and the increased specialization worldwide are important drivers for the globalization of trade and economic growth. Freight transport has been growing both internationally, in Europe and domestically in Denmark, although disrupted by the recent economic recession.

One of the key issues of interest in domestic freight transport where a transfer to rail from truck is seen a less feasible than on a continental scale, is the capacity utilization of trucks. The utilization is likely influenced by a number of factors, including shifts in the commodity base towards higher value goods, the increased use of for hire transport, an increase in vehicle size, and changes in handling factors (Kveiborg and Fosgerau 2007). The freight transport analysis investigates such trends and what they may imply for regulation of freight transport.

I.7 Limits addressed in the study

‘Limits’ are here viewed as mechanisms, factors or constraints that limit or suppress transport demand from being realized or some aspect or mobility (understood as potential transport) from being available. Limits to transport demand and mobility can arise if capacity in the system is used (e.g. congestion) or they may be imposed via policy measures in order to avoid externalities or achieve certain policy goals (e.g. via land use plans, or taxation).

The limits considered are highlighted in Figure I.3 and include,

- Climate change
- Spatial constraints
- Public budgets

The study does not assume or seek to define any absolute limits in these areas. However they are key impact areas that policy makers are concerned with, and which could release interven-

tions into various aspects of transport demand if current trends are not reversed and technological solutions prove insufficient or inexpedient.

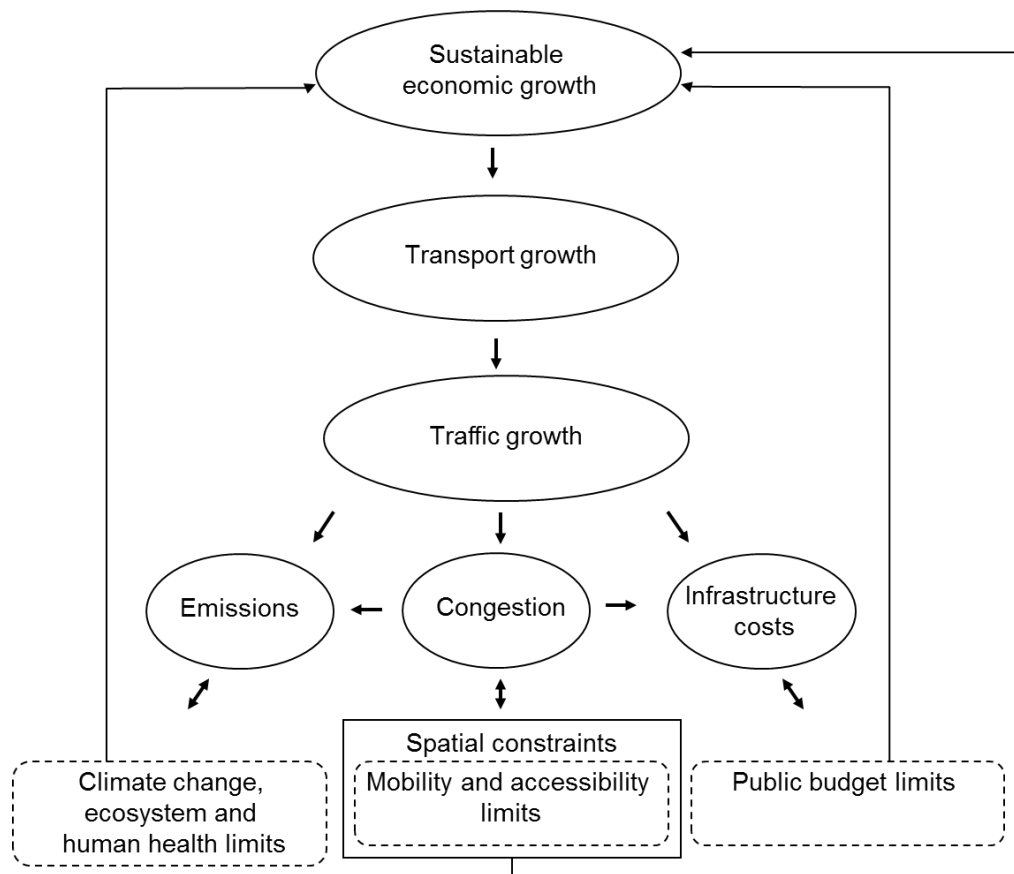


Figure I.3: Limits to Travel Demand considered in the present study

I.7.1 Climate change

CO₂ emissions continue to be the most important greenhouse gas and its rapid increase in the atmosphere is due to burning of fossil fuels. Global agreement has been reached that a temperature increase of 2 degrees C above preindustrial levels is a limit beyond which dangerous interference could occur and should be avoided (UNFCCC, 2010). Climate changes has been identified as one of the most significant 'planetary boundaries' to human activity (Rockström et al., 2009). Transport is one of the main emitting sectors globally as well as in Denmark, and the only one that has seen substantial growth until recently. Road transport is responsible for the majority of the overall transport emissions.

Unobstructed GHG emissions could in the long run lead to climate change effects, including rising sea levels, and increases in flooding that could eventually disable parts of the infrastructure and directly limit mobility also in Denmark. Such possible future direct limiting effects are not currently known.

The European Union has estimated that a reduction of at least 60% of GHG by 2050 with respect to 1990 is required and that at least 20% by 2030 compared to the 2008 level (European

Commission, 2011). In Denmark the transport sector represents 34% of the total final energy consumption and is, as opposed to the industry and household sector, the only sector that has continued to increase its energy consumption. (Energistyrelsen, 2009). No specific emission targets have been defined for transport but the government has made it clear that transport must contribute to the goal of 40% emission reductions in 2020 for the country as a whole and to Denmark's energy supply becoming fully based on renewable energy by 2050 (Danish Government 2013).

In Part III we will review policy implications if the findings reported in Part II with regard to climate change.

I.7.2 Congestion / Use of Space

Growing urban congestion is a source of major concern to all societies. Congestion can be viewed as a problem of capacity and efficient use of space (road, runway, rail etc.). In economic terms it can be understood as a classic problem of market failure in the form of uncompensated time loss imposed on others. Furthermore congestion may exacerbate environmental problems such as air pollution, GHG emissions and barrier effects.

An absolute - albeit temporary - limit for a segment or a network could be defined as the level of capacity exceedence that brings traffic to a halt. Most cities and other regulating bodies intervene proactively or reactively to avoid reaching this limit for more than short segments and time periods. The traditional solution is to expand the infrastructure, while demand management measures are increasingly applied as supplement, including congestion charging on the road network adopted in a few cities worldwide. While theoretically well justified, congestion charging tend to be complex, expensive to administer, and politically unacceptable (May and Nash, 1996; Santos, 2005; Borjesson et al., 2012). Other measures such as parking charges, and incident management are more widely applied.

Congestion provides a fluid subject of debate in Denmark and a variety of measures and methodologies are contemplated as relevant as new information emerges. Recently, in Denmark the efforts to implement a congestion pricing ring in Copenhagen evolved into a highly politicized process that led to the cancellation of the plans. A government Commission (Trængselskommissionen, 2013) has proposed a package of alternative solutions. Section III will review policy implications if the findings reported in Part II with regard to congestion.

I.7.3 Public Budgets

Limited public budgets are also widely seen as a constraint to cope with increasing traffic volumes though traditional expansion of the infrastructure networks (ITF, 2013M; OECD, 2006b; ECMT, 2005). Several countries are putting increasing emphasis on the need to utilize, manage and maintain existing infrastructure better, while also attracting new sources of funding, as strategic complements to conventional tax-payer funded investments in new infrastructure (see, e.g. (HM Treasury, 2010; Aparicio, 2010; Nash et al., 2009; Government of Japan, 2008; Pakkala et al., 2007).

Some interpret this change as part of a possible shift towards more sustainable transport policies and practices that may also help alleviate climate change and congestion impacts (see e.g. Toleman and Rose, 2008).

The need to secure adequate resources for maintenance of the existing infrastructure, even potentially at the expense of some further infrastructure capacity expansion capacity has also been observed in Denmark (Finansministeriet, 2001; ATV, 2001), and it has been widely noted that further public infrastructure expenditure may not be the optimal way to solve all problems associated with rising congestion (e.g. KRAKA, 2012; DØR, 2006; Trafikministeriet, 2004). Fiscal constraints on investments do however not appear to be the most significant concern in the context of Danish transport policy (see e.g. Infrastrukturkommissionen, 2008), nor in the more restrictive control regime for public budgets currently being implemented in Denmark (Nielsen and Rasmussen, 2012). The topic has not been a key focus on the Drivers and Limits study.

1.8 Summary from PART I

A consolidated and unique approach to understand and apply drivers of demand does not exist in the research literature. The background exposed with the overview of studies in this introduction suggests that drivers are contextual and can be defined, distinguished and analysed in a number of ways. An approach that is specific and detailed in particular areas is well justified in comparison with a synoptic approach seeking universal explanations and models.

External drivers to transport can be very significant but still difficult to quantify. The quantification of drivers on the other hand may not always be necessary, depending on the scope of the study. Drivers can be used in the form of principles to advance goals. Drivers can always be discussed in connection with areas deemed to need attention in the public and policy realm. Continued research to understand drivers of travel demand is necessary as indicated in the literature, not least to cope with external effects and limits such as climate change and congestion. Limits are not absolute even if they can be severe and immediate.

Limits like those considered here: climate, congestion, public budgets can hardly be ignored and are in fact far from ignored today. They are fundamental to the reproduction of mobility opportunities and to the efficient operation of the system as well as existing policies. Each of the boundaries can be stretched, but at the peril of jeopardising welfare and the conditions supporting quality of life in cities, modern lifestyle, as well as - eventually - planetary boundaries.

Avoiding the limits may require policy intervention on drivers. The most common approach in Danish policy interventions is directed to impact drivers inside transport sector (value of time, transport cost, technology, infrastructure investment, public transport investment).

The reviewed studies have identified a number of drivers inside and outside transport which are of similar importance but likely at different levels: globalization, demographics; socio-economic status; urban form and land use, parking, and several others.

The following Part II presents the results of the different areas of study within the Drivers and Limits project.

PART II: Summary of Results

II.1 Socio Economic and Demographic Factors

II.1.1 Motivation

This area addresses issues of individual travel demand in a life course perspective. The mobility patterns of different age groups have a distinct and significant impact on current and future total transport demand. This research gives focus to three age groups:

- 1) The large post-World War II cohorts, the so called “baby-boomers”
- 2) People just before turning 70 (age at which they need to renew their driving license for the first time) and
- 3) Young road users aged 15-34.

The mobility aspects for each age group are modal choice, in particular car-use- and, everyday travel behaviour. The research investigates the relevance of socio-economic, demographic and cultural drivers and limits influencing individual transport demand and, it gathers knowledge and opinions about environmental friendly travel transport patterns.

Altogether 2618 persons have been surveyed, 1727 of them both in 2009 and 2012. Table II.1 provides an overview of the surveys and included samples.

Table II.1: Survey design							
Age group / cohort	Survey type	Survey date 1	Sample size 1	Response rate 1	Survey date 2	Sample size 2	Response rate 2
1946-47 ("Baby boomers")	CATI ¹	Nov-Dec 2009	1772	74%	Jan-Feb 2012	864	78%
1939-40 ("Renewers/Non-Renewers")	CATI ¹	Nov-Dec 2009	1792	70%	Jan-Feb 2012	863	77%
1995 (15 years old)	Online survey	February 2011	3025	30 %	-	-	-
1995 (15 years old)	Qualitative individual in-depth interviews	June-July 2011	50	100 %	-	-	-

¹standardised computer-assisted telephone interviews

The first sub-group, the “baby-boomers” are expected to influence individual transport demand as they will comprise a large share of tomorrow’s older population. Studies on baby boom cohorts’ social and cultural characteristics as well as studies on the third age are important in understanding the impacts the demographic turn of baby boomers retiring will have on the transport sector. The area of study is still emerging. We know, however, that the life course of the baby boomers has been shaped rather differently from that of their parents. For example, they have benefited from the development of the welfare system (including pension schemes), healthcare innovations and economic growth (e.g. Keister & Deeb-Sossa, 2001). They have al-

so gained formal education to a much greater extent than their parents' generation (Eurostat, 2011) and due to the size of their cohort, they have had a large critical mass in society and consequently much more political and societal power (e.g. Dychtwald, 1999). In addition they were the first generation to be born into and live their whole lives in a society with modern mobility, characterised by automobility and long-distance leisure travel (Coughlin, 2009). Consequently, when entering into old age, the baby boomers are likely to differ from their parents or grandparents: they are healthier, lead more active lifestyles, with different consumption patterns, attend various leisure activities, travel more often and over longer distances and have more economic resources (e.g. Moschis & McArthur, 2007). Against this background, the travel habits, attitudes and expectations of the baby boom cohort in Denmark were explored, with a focus on gender differences and the heterogeneity of the group. We further analysed, in how far baby boomer's travel habits and future expectations changed after retirement.

The second subgroup, people turning 70 years of age are in a sense at the verge of entering the group of "older road users". In Denmark, the driving license is valid until the driver reaches the age of 70. Thereafter, it needs to be renewed at the age of 70, 74, 76, 78 and 80 and then every year. Age-based restrictions on driving have recently been under debate and heavy criticism (e.g. Desapriya et al., 2012; O'Neill 2012a,b.) Recent studies have indicated that screening procedures do not only fail to produce the desired safety benefits but are connected to various direct and indirect costs and may even decrease the overall safety (Siren & Meng, 2012). Driving cessation is likely to decrease both the mobility and the safety of the former drivers, since alternative travel options are often insufficient, unattractive, and less safe (OECD, 2001). It further reduces out-of-home mobility in general (Marottoli et al., 2000) and is associated with a decrease in experienced personal mobility options (Peel, Westmoreland & Steinberg, 2002; Taylor & Tripodes, 2001), depressive symptoms (Fonda et al., 2001; Marottoli et al., 1997; Ragland, Satariano & McLeod (2005), declines in physical and social functioning and general health (Edwards, Lunsman, Perkins 2012, Rebok & Roth, 2009). Against this background, Danish drivers were asked, just before turning 70 years of age, about their thoughts and intentions regarding renewing their license, the reasons for renewing or not as well as about their travel habits before and after renewing the license.

The third and final subgroup in this study consists of young people aged 15-34. Compared to the other two subgroups this subgroup is expected to influence the individual transport demand over the longest period of time as they are active users of the transport system today and will most likely be using it for many years in the future and thus impact the individual transport demand in the future. Therefore, a key to understanding and anticipating changes and possible policy interventions towards more environmental friendly travel choices lies in a greater understanding of drivers and limits influencing the individual travel demand of the younger generations. The conceptual framework of the socio-ecological model and the theory of planned behaviour were applied.

Only a very limited number of studies have been performed in the Nordic countries within this area (Nordbakke & Ruud, 2005). Against this background and based on National Travel Survey trends in the travel pattern from 1995 to 2012 among road users aged 15 to-34 was described with regard to aspects such as mode choice, transport time and trip length while taking gender and residence into consideration. In addition a survey including 891 youngsters aged 15 was

conducted with the purpose to map their intentions to commute by car and/or bicycle as future adults. In addition their environmental concern (transport related as well as in general) was analysed.

Young people are in their formative years with regard to individual travel behaviour (Mackay, 1998). They are in a transitional stage between childhood and adulthood psychologically, economically and practically and are thus in the initial stage of adopting new individual travel patterns and habits of their own. Consequently, their travel patterns and mode choices are open to influence (Line et al., 2012). At the same time, based on influence from family, friends, school and media it is expected that they have already established certain travel habits, preferences as well as opinions about different transport modes. The process through which such travel habits and opinions are established are not yet fully understood, but the concept of travel socialization has recently proven to be a useful conceptual frame (Haustein et al., 2009). Building on previous research the motivations underlying adolescents' intended time-frame for obtaining a license and purchasing a car was explored. In addition issues such as the nature of transport related environmental concern, suggestions regarding possible solutions and measures promoting climate friendly transport as well as perceptions regarding own influence were explored using a qualitative approach.

II. 1. 2. Results/Findings

The travel behaviour and expectations of the "baby-boomers" were analysed based on 1772 standardized telephone interviews. In general, the baby boomers reported being healthy, independent and highly automobile dependent. They were also optimistic regarding their level of mobility, use of different modes of transport and ability to lead an independent life in the future. Significant gender differences in terms of present and expected car use in old age were found, similar to those observed in older cohorts. Using cluster analysis, three segments of baby boomers were differentiated based on their future expectations: they were called Flexibles, Independents and Restricted subjects (see Figure II.1.).

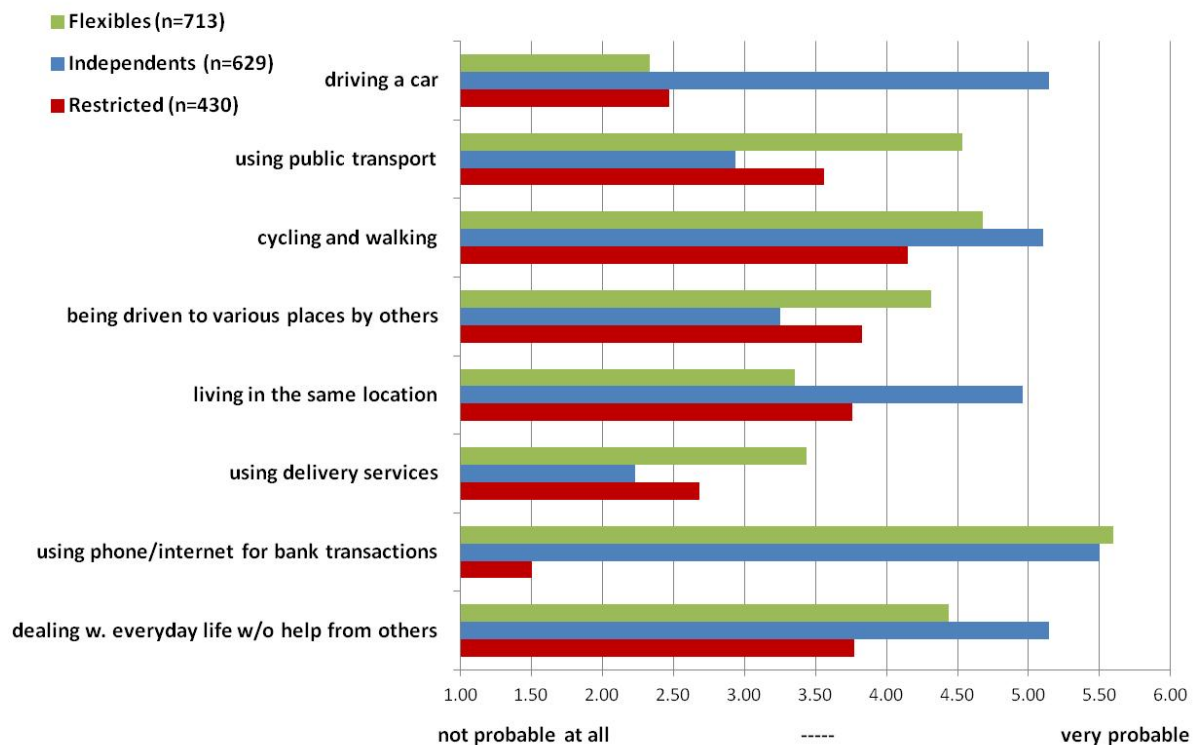


Figure II.1: Segments of Baby Boomers based on their future expectations (aged 80)

The “Flexibles” expected to use all modes of transport but the car at the age of 80. Furthermore, they expected to be using the Internet or a telephone for banking transactions and to make use of delivery services. “Independents” expected getting along without help from others and still using primarily individual modes of transport, i.e. driving a car, cycling or walking. They also imagined using the Internet and telephones for transactions, but no delivery services. Members of the third and smallest cluster expected to be restricted in their use of all modes of transport, and especially in car use. They are most in need of support but are at the same time less open to technical services that could disburden their everyday life. The three sub-groups also differed in terms of their current travel behaviour and living conditions. While the “Independents” reflected the general tendencies of baby boomers with a high level of reliance on cars, and the “Flexibles” reflected the tendency to be open to different modes and services, the “Restricted” group deviated from the general picture. This group’s need for external support will probably be much larger than that of the two others. In this sense, the boomers’ future needs will probably not differ completely from their parents’, and the differences between the “new old” and “old old” in terms of independence and the need for support may be smaller than intuition suggests. This is further supported when this study’s findings are compared to previous studies that have identified sub-segments of older people in terms of transport (e.g. Haustein, 2012; Hildebrand, 2003). The results are reported in more detail in a paper by Siren & Haustein (2013).

Based on a follow-up with 864 participants of the first survey, changes in travel behaviour due to retirement among baby boomers were explored. We found a clear tendency to reduce the overall level of car use and mileage over time and as a consequence of retirement. By contrast, car use for leisure purposes increased after retirement. Retirement was found to have a bigger im-

pact on men's than on women's car use. However, those women who continued working had a high car reliance that did not show decline over time (see Figure II.2).

The present study suggests that retirement is a transition point that decreases car use. Hence, the population ageing is likely to have a decreasing effect on transport demand. However, the emergence of leisure and consumption as major cultural and social frameworks of the third age, prolonged careers and atypical working life, informal care giving, and boomer women's changing professional roles are likely to make this transition different than observed in previous cohorts. The results are reported in more detail in a paper by Siren & Haustein (submitted A).

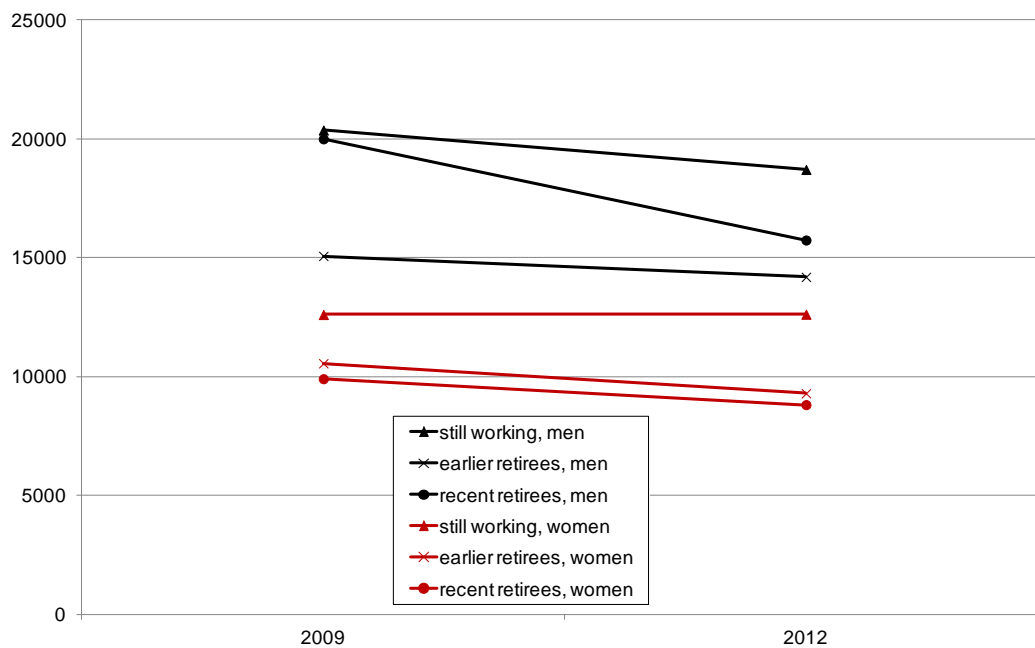


Figure II.2: Kilometres driven by working status and gender

The study among persons turning 70 years of age revealed that the majority of older Danish people intent to renew their license (93%) and also do so when reaching the first license renewal milestone. Those who renewed their license differed from those who choose not to renew with regard to health status, dependency on others, or feeling safe as a driver. Main reasons for not renewing the license were simply not wanting to drive anymore followed by health related and financial reasons. Predicting driving license renewal intention in a regression analysis, 4 out of 13 predictors became significant, namely car use frequency (which was the strongest predictor), dependency on others, illnesses impairing driving ability, and feeling safe as a driver. Gender was not significant itself but associated with lower car use frequency, feeling less safe as a driver and depending more on others. The results are reported in more detail in a paper by Siren and Haustein (forthcoming).

Comparing data from before and after renewing the license, we found that non-renewers and renewers differed significantly in travel patterns and health status already before renewing (or not) their license. Health status of non-renewers did not decrease more from 2009 to 2012 than renewers', so that poor health seemed to be more likely a cause than an effect of driving cessa-

tion. While the participation in different activities did in most cases not differ significantly between renewers and non-renewers, non-renewers reported more unmet mobility needs both in 2009 and 2012, especially in relation to leisure activities. The relation between driving cessation and unmet travel needs remained significant even if health and other background factors were controlled for, indicating that giving up the license increases existing restrictions in mobility. The results are reported in more detail in papers by Siren & Haustein (submitted B). An additional paper focuses on older people who never owned a license and compares them with renewers and non-renewers. While it was expected that they can better compensate for not being able to drive than non-renewers, we found that both never owning a licence and not-renewing a licence has a negative impact on unmet travel needs (Haustein & Siren, in preparation).

With regard to trends in the travel pattern among the 15 - 34 year olds no systematic gender gap in licensing was found in urban areas (Sigurdardottir et al., 2013c). In rural areas, a significant gender gap was found for young people in their twenties, with males having a higher licensure rate. The gap is irrelevant for people in their thirties since almost all have a driving license by this age. Hence, while women exhibit a delay in obtaining the license compared to men, most of them acquire a license by their early thirties. Regarding car accessibility, no significant gender gap was found in urban areas, while in rural areas young women in their thirties enjoyed a slightly higher car accessibility compared to men. The gender gap in the number of trips increased with age (see Table II.2) Thus the most pronounced systematic gender gap both in rural and urban areas was found among the 30-34 year-olds, with females having a much higher number of trips. In terms of daily driving female young adults travelled significantly shorter distances than males in the 1990s. The gap has remained significant only for 30-34 year-olds in urban areas.

Table II.2: T-statistics for the comparison between the daily trips of males and females by age and region								
Year	Rural 15-19	Urban 15-19	Rural 20-24	Urban 20-24	Rural 25-29	Urban 25-29	Rural 30-34	Urban 30-34
1995	-0.85	1.58	-0.52	0.27	0.66	1.44	-1.65	-2.97
1996	0.06	0.10	0.82	0.88	-0.91	-1.31	-3.62	-1.18
1997	0.28	0.08	0.15	1.37	-1.88	-0.82	-2.69	-0.15
1998	0.71	-0.48	-0.79	-0.46	-2.28	-1.58	-2.12	-1.95
1999	0.48	1.59	-1.16	-0.92	-1.69	-0.19	-1.31	-1.87
2000	0.73	1.15	0.52	-0.15	-1.49	0.17	-4.00	-3.38
2001	0.31	2.75	-1.04	-0.70	-1.37	-0.58	-4.50	-3.30
2002	-1.64	0.66	-1.39	-0.73	-3.12	-1.64	-3.00	-2.17
2003	2.00	1.66	-1.55	-0.45	-1.87	-0.90	-5.43	-1.94
2007	0.31	-1.74	-2.88	-2.90	-1.28	-3.29	-1.24	-1.48
2008	-1.52	-1.71	-1.03	0.22	-2.20	0.55	-2.20	-1.95
2009	-1.89	-2.45	0.38	-3.75	-0.68	-1.66	-4.82	-2.16
2010	-2.21	-0.57	0.59	-2.49	-3.19	-2.54	-3.79	-1.78
2011	-2.13	1.04	-1.64	-1.67	-2.46	-5.17	-3.07	-3.29
2012	-0.01	0.12	-1.03	-1.66	-3.31	-0.01	-2.00	-2.22

The travel time has increased by 10-20% for both males and a female from 1995 – 2009 but no gender difference in the growth was identified. A significant gender difference regarding travel purpose was found among the 25-34 year olds with males engaging in more mandatory trips

and females engaging in more escort trips. For the 25-29 year-olds, the difference was only found in rural areas while for the 30-34 year olds the difference was found both in urban and rural areas. With regard mode choice a significant difference with males travelling more by car and females travelling more by non-motorized modes in the 1990s became non-significant in recent years except for people aged 25-29 living in rural areas (see Table II.3).

Table II.3: Pearson's chi-square (p-value) for comparing the mode shares of males and females by age and region								
Year	Rural 15-19	Urban 15-19	Rural 20-24	Urban 20-24	Rural 25-29	Urban 25-29	Rural 30-34	Urban 30-34
1995	0.03	0.02	0.02	0.05	0.86	0.64	0.54	0.39
1996	0.00	0.01	0.00	0.12	0.65	0.24	0.18	0.02
1997	0.01	0.03	0.00	0.01	0.87	0.46	0.04	0.05
1998	0.08	0.46	0.00	0.10	0.00	0.17	0.93	0.72
1999	0.71	0.54	0.00	0.09	0.96	0.19	0.03	0.05
2000	0.03	0.16	0.37	0.05	0.01	0.08	0.75	0.59
2001	0.10	0.00	0.01	0.12	0.00	0.04	0.89	0.24
2002	0.00	0.05	0.00	0.25	0.29	0.40	0.14	0.04
2003	0.07	0.04	0.57	0.01	0.00	0.23	0.28	0.38
2007	0.00	0.63	0.21	0.02	0.85	0.70	0.78	0.37
2008	0.64	0.79	0.38	0.26	0.03	0.35	0.02	0.64
2009	0.76	0.33	0.48	0.10	0.08	0.29	0.80	0.73
2010	0.61	0.79	0.02	0.23	0.96	0.67	0.46	0.18
2011	0.17	0.01	0.01	0.49	0.34	0.11	0.01	0.54
2012	0.28	0.04	0.43	0.13	0.02	0.62	0.60	0.50

The result suggest that in Denmark, in cases where there is a gender-related gap in transport behaviour, the gap progresses across age groups and is different for rural and urban areas. Regarding the number of trips and the proportion of trips by purpose, the gap is greater for the older age groups and is more pronounced in rural areas. Regarding the travel distance, the gap over time diminished more rapidly in rural than in urban areas, and currently the gap is significant only for the oldest age group in urban areas. Regarding the trip proportion by mode, the difference is more pronounced in rural areas, and it diminishes with the lifecycle progression.

Based on the survey data it was found that more than 80% of the adolescents intended to learn to drive and own a car. 47% stated that they would like to drive to work in the future whereas 28% would like to take the bike. In comparison 34% would like to take the car and 43% would like to take the bike to leisure time activities. In addition it was found that the car use intentions were related to positive experiences as car passenger, general interest in cars and car ownership norms and were negatively related to willingness to accept car restrictions and a perceived lack of behavioural control (Sigurdardottir et al., 2013b). Similarly, cycling intentions were related to positive cycling experience accept car restrictions, negative attitudes towards cars, and a bicycle-oriented future vision and negatively related to car ownership norms (see Table II.4). A gender difference regarding attitude towards cars and environmental concern was found showing males to be more car-oriented and less concerned with transport related environmental issues.

Table II.4.: Structural equations - hypothesized model structure

Dependent latent variable	Explanatory latent variable	Estimate
Willingness to accept limitations on car travel	Environmental concern	0.415 ^{***}
	Social influence encouraging environmental concern	0.683 ^{***}
	Car-oriented future vision	0.363 ^{***}
Intentions to drive to work by car as a future adult	Subjective norm of car ownership	0.370 ^{***}
	Willingness to accept limitations on car travel	-0.624 ^{***}
	Perceived lack of behavioral control	-0.254 ^{***}
	Positive experience as a car passenger	0.811 ^{***}
	General interest in cars	0.700 ^{***}
Intentions to cycle to work as a future adult	Positive cycling experience	0.543 ^{***}
	Negative attitudes towards cars	0.396 ^{***}
	Subjective norm of car ownership	-0.251 ^{***}
	Willingness to accept limitations on car travel	0.423 ^{***}
	Bicycle-oriented future vision	0.275 ^{***}
Correlation across intentions		
Intentions to drive to work by car as a future adult	Intentions to cycle to work as a future adult	-0.785 ^{***}

Notes: * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level

The qualitative approach revealed differences regarding the 15 year old youngsters time-frame for obtaining a license and purchasing a car (Sigurdardottir et al., 2013a). Three groups were identified: car enthusiasts, car pragmatics and car sceptics (see Table II.5).

Table II.5: Time-frame to obtain a driving license, own a car and the attributed value of the car

	Licence	Car	Instrumental value	Affective value	Symbolic value	Relational value
Enthusiasts	Now	Now	High	High	Positive self-image, large/fast cars	Cruising
Pragmatics	Now	Later	High	Medium	Positive self-image, functional cars	Chauffeur
Sceptics	Later	Later	Low	Low	Negative self-image, prefer car-go-bikes	None

The car enthusiasts would like to obtain a license and a car as soon as possible. They had a high interest in cars and associated them with high affective, symbolic, and relational value, and moderate instrumental value. They perceived no barriers to car ownership and use, they had strong negative emotions to a life without a car, and their car-oriented family and friends shared the same car enthusiasm. Car pragmatists associated cars with high instrumental and relational value and low affective or symbolic value, and perceive car expenses as the main barrier to car ownership. Their families encouraged them to obtain a driving license and to share the car within the household as adults. They believed that the quality of their life only would be affected in the long-term perspective. Car sceptics had a low interest in cars, associated low instrumental and relational value to the car and associated car ownership with negative environmental impact and financial expenses. Their families were bicycle-oriented and exhibited high environ-

mental concern. Their perceived quality of life would not be negatively affected by not having a car.

II.1.3. Synthesis and Perspectives

In the coming years, when the baby boomers become “older road users” they will be conforming a group that is characterized as a strong consumer of transport system services, high demand for mobility, good resources and with optimistic expectations about personal mobility in old age. Heterogeneity within this group is a factor that plays a part in this group’s demand for travel. The differences between women and men are large and somewhat similar to those observed in older cohorts. Other sub-groups of boomers can also be identified, and these differ greatly in terms of mobility resources and expectations. Thus, overly optimistic scenarios about independent boomers whose need for external support in old age will be minimal may be unrealistic. Modern social policies have increasingly emphasized individual and family responsibility rather than state responsibility to meet the needs of older people (Quine & Carter, 2006), but whether this is a feasible and reasonable solution, even for the boomers as they age, is questionable.

With regard to the age group that just turned 70 it has been shown that the majority continues driving despite the renewal procedure. While driving cessation was associated with mobility problems, those persons not renewing their licenses had already restricted their driving or stopped driving entirely before reaching the renewal age. The economic and safety returns of the age-based driver screening policies have been shown to be poor (Langford et al. 2004; Siren and Meng 2012) and some studies indicate that having such policies in place may actually decrease the safety (Hakamies-Blomqvist et al., 1996; Siren & Meng, 2012; Tay, 2013). At the same time, the economic and safety benefits of independent mobility in old age are indisputable (e.g., Hakamies-Blomqvist, 2003) making prevention of premature driving cessation and the consequent mobility loss justified. Having restrictive, ageist policies in place that moreover fail as societal investments, may however work against society’s goal of preventing unwarranted mobility loss in old age.

For the young subgroups results generally indicate that young people imagine their travel pattern as future adults as highly car oriented as the large majority intend to obtain a driving license and purchase a car at some point. At the same time results indicate a potential towards reduced car use based on a general willingness to alternate between the car, the bicycle and public transportation and an embracement of technological developments to enhance sustainable transport. The potential for decreased car use is apparent in several ways. Firstly, a comparison of the stated intentions and realized choices regarding mode choice indicates that the intentions are only partially realized. Thus at the age of 15, 47% intends to take the bike to work. At the moment only 24% of people in their twenties and 19% of people in their sixties do so. Thus, there appear to be a potential for increased bike use. Secondly the potential for decreased car use is emphasized by the identified differences regarding the time-frame for their obtaining a license and purchasing a car. Even though some youngsters intend to use a car as soon as possible, other youngsters with positive experiences or role models using alternative transportation intend to postpone either the buying of the car or both the license and the car. Thus, policy measures that support the use of the bicycle and public transportation from an early age and into early family life is likely to increase the use of alternative modes of transport and to increase the willingness to accept restrictions on car use. Similarly, financial measures are likely to post-

pone the use of the car, as the financial expenses related to licensing and car ownership appear to be a barrier towards early car use for some youngsters.

II.2 Long Distance Travel

II.2.1 Motivation

Rising incomes, globalisation, increasing leisure time, and earlier retirement makes it possible for people to spend more time on leisure trips (Mokhtarian and Salomon, 2001) along with sharply falling costs of long distance transport, due to e.g. liberalisation and increased competition in air and other transport services. So far most studies of passenger transport have concentrated on shorter daily travel and little is known about long distance trips. However, long distance trips account for a significant and increasing part of transport, for passengers as well as for freight (EEA, 2008c), and thus for the negative externalities associated with transport. In this light, the lack of knowledge about long distance passenger and freight transport and the exact effect of the anticipated drivers is an increasing problem.

There is a need to increase the knowledge of long distance travel and the associated demand patterns. Analysis in the project has been developed with the aim of elaborating the present demand as well as the historical development of national and international long distance travel to and from Denmark as far as data allows. Destinations, distances and transport modes for different journey purposes was analysed based on the Long distance Travel Survey, Statistics Denmark's Holiday and Business Travel Survey, the SABRE database of international air travel, and airport statistics from Trafikstyrelsen.

II.2.2 Results Findings

Completed results from the analysis of the Holiday and Business Travel survey, and results from the analysis of SABRE based time series are presented in this section.

Holiday and Business Travel Survey 1997-2008

The influence of socio-economic, demographical and geographical factors on long distance travel was explored by means of the Business and Holiday Survey. The survey is available from different points in time and a comparison between 1997/99 and 2006/08 is supported by the data.

The research focussed on upon 4 factors: gender, age, income and region of residence. Clearly these factors are related. Specifically, income varies for different age groups and regions, and also between men and women. Gender differences in international journeys and the difference between 1997/99 and 2006/08 are presented in Figure II.2.1.

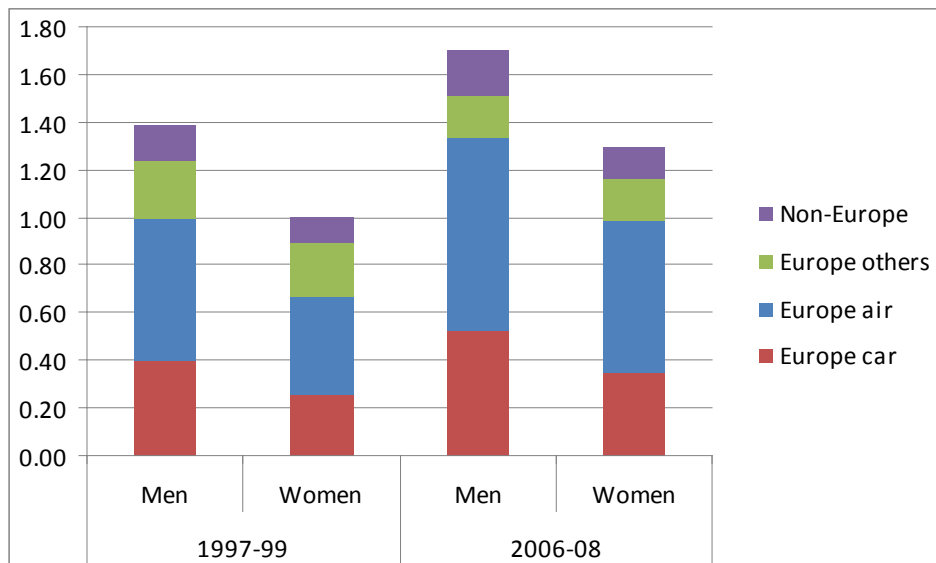


Figure II.2.1: International journeys pr. Dane per year, split into non-European destinations, and European destinations by car, air and other modes.

The main conclusions from the descriptive study was that the frequency of international journeys are highest for men; for individuals in the age group 41-60; for individuals with high income; and for individuals residing in the Greater Copenhagen area.

The frequency of international travel in the population is seen to increase with age but tend to decrease again after the age of 60. For urban and regional context a high frequency of international travel is clearly a trait of urban populations and markedly higher in the Capital area. The regional differences may be due to income differences, life styles as well as accessibility to international destinations.

Changes between 1997/99 and 2006/08 which was particularly noticeable for women, and low income groups that displayed higher growth rates than men and higher income groups respectively. The changes for the low income group indicates some catching up in rates of travel, but generally growth applied to all groups and differences in orders of magnitudes were maintained through the period.

Demand analysis based on SABRE air travel data

The object of this study was to examine the drivers of demand for international air travel by Danish residents, exploiting SABRE and Airport data to compile time series and include air travel fares. Air travel fares have changed markedly through recent decades due to increasing competition.

Sabre is a computerised reservation system used in the travel industry reporting ticket sales for scheduled air travels. Information is available as monthly aggregate data for 2002-2012 on the number of passengers, revenue and average fares by origin/destination (airport, city, country), airline, cabin class, connections, and country of ticket purchase. The Airport database supplements Sabre data with information about charter travel and flight operations. A pooled time-series dataset for air travel between Denmark and 66 countries by Danes was developed.

The analyses concluded that the overall person kilometres made by Danes as air traffic has increased 80% over ten years making an increase rate of 7.2% per year in mean. It should be mentioned that person kilometres by car at international travels has increased too resulting in an increase in the environmental burden which is several times higher than the increase in national travels in the same period. The increase in Dane's air travel is due to a 73% increase in European travels, 104% increase in non-European travels and an 8% increase in the mean travel distance due to the changed composition of travel destinations. The increase in the mean distances has happened even though the mean distance has decreased both inside Europe and at overseas destinations.

The destinations for the air travels are rather stable with Spain and Great Britain as the two most important destination countries representing around 22% of the travels. The typical business air travel destinations Germany and Norway has increased in importance and Sweden has decreased as an air destination due to the Oresund Bridge. For the overseas travels Egypt and United States have increased in importance. Charter travel still plays a role to the Mediterranean countries for which Turkey has taken over some of the attraction from Greece. The 19 most important destination countries represent just around 80% of the travel market in 2002 as well as in 2012.

The efficiency of the network of air traffic out of Denmark has increased with more passengers per flight, except for the long-haul flights. The number of destinations has increased, but with less operations per destination. Concentration in the scheduled network from Copenhagen has increased since 2007 offering less daily or weekly departures to small destinations resulting in a slight concentration of passenger destinations.

The competition measured by number of airlines and their market share has increased very little, for non-Europe 6%, for Europe less and only up to 2005. Between 2002 and 2012 the number of passengers by Low Cost Carriers has increased 300% for Europe and 600% for non-European destinations. The increase in Low Cost destinations has resulted in decreasing prices for other airlines for European destinations for which the mean price today is close to Low Cost prices. For non-European destinations development in low cost has not yet affected the prices of the flag carriers.

The model analysis shows that air travel first of all is affected by increasing income for which the long run elasticity is 2.0 (little higher for Europe than non-Europe). Prices are not quite as important for the increasing number of travels, the fare elasticity for Europe is -0.25 and for non-Europe -0.33.

II.2.3 Synthesis and Perspectives

Long distance travel is increasing rapidly. The project has approached the topic based on new cross sectional data as well as the best available time series data. Increasing travel frequencies apply to all groups, but there is some trend towards a levelling of differences due to lower relative growth among the most frequent travellers. Lower fares and especially higher incomes are important explanatory factors as indicated by analysis in the project. A pressing problem is, however, that long distance travels crosses borders and is poorly represented in existing national surveys and datasets. Thus, the analytical capacity and understanding is poorly devel-

oped compared to national and intraurban travels. As European integration increases and long distance travel grows into a larger and larger share of travel and transport related energy use etc. this produces a knowledge gap.

II.3 Land Use and Urban Form

II. 3.1 Motivation

Urban form, infrastructure and transportation creates a wide research area fuelled by diverse strategic interests such as the assessment of effects of infrastructure projects, the role of urban areas as generators of traffic in transportation modelling, and lastly the possibility of achieving sustainability and energy efficiency outcomes from the combined implementation of urban planning, land use and transport policy integrated strategies. The societal challenges include the understanding and management of effects of transport infrastructure and interaction patterns upon urban systems; as well as the understanding and management of infrastructure and urban form effects upon active and sustainable transport behaviours.

However, in the study of causal dynamics and relations between aggregated land use urban form, transport interactions expressed as demand for travel, multiple lacks of knowledge still exists. Most prominently knowledge is lacking in areas like adequate representation of urban form and services in analysis; knowledge of what apply in different types of regions; and knowledge of how transport-land use interactions develop or change over time. Furthermore issues of causality and sizes of effects generally have remained disputable.

Advancing the resolution to many of these questions can help solidify the soundness and credibility of knowledge as inputs to decision support. The main contribution of this area of the project is to address some of those knowledge gaps taking advantage of the options provided by the available micro-data from the Danish public registers and the rolling National Travel Survey. These two main sources provide an excellent base from which to develop new insights on personal transport, commuting, employment, and wages in relation to urban form, infrastructures, and commuting distances.

With the use of these data bases the project advanced three major research topics: The first looked into how *land-use – transport associations* applied in the large metropolitan areas as they grow more polycentric; as well as what apply in the more balanced polycentric regions that are often provincial regions. The project studied two regional 'cases': the provincial highly polycentric metropolitan region of East Jutland and the region of Zealand which include the metropolitan region of Copenhagen and some of the surrounding peri-urban areas. Commuting behaviours where studied in East Jutland for their correlation with urban form; changes over time, and differences towards the more monocentric urban region of Copenhagen. Additionally the role of subcentres towards travel behaviours and their changes over time was studied for the region of Zealand to allow an assessment of stability or fluctuation in urban form correlates of travel.

The second area project studied the case of relocating employers, increasing *commuting distances and its effect on wages* as an important building block for an improved understanding of the dynamics behind increasing travel and commuting distances and of the distribution of its

economic burdens. An additional topic that followed was the occupancy of parking spaces which was studied based on a street level dataset representing pricing and occupancy rates provided by the City of Copenhagen.

The third area of research study considered the *effects of new transport infrastructure* on travel behaviour. It was developed based on the opening of the 1-phase of the Copenhagen metro. Danish register data allowed observation of behavioural changes in the population residing in the area prior to the metro and experiencing the accessibility improvement from access to the new metro stations.

II.3.2 Results/Findings:

Land-use – transport associations

With the development of the main theme on transport and urban form the study focused on understanding the effects on travel of polycentric urban/regional contexts. Many previous studies have focussed on transport and urban form in larger urban areas and concluded on the role of centrality in determining transport patterns (e.g. Nielsen, 2002; Næss 2006a) but the significance of the polycentric urban context for such effects is highly neglected. Polycentricity refers to urban regions with multiple activity centres that are relatively equal in size. Some degree of polycentricity applies to all urban regions as growth over time often leads to the development of subcentres outside the urban core. The increasing interaction distances (commuting and similar) and the dense urban system, which is found in most European countries also tend to create functionally integrated urban regions, but with spatial separation between the nodes and a high degree of 'balance' in the region – i.e. no single city is highly dominant/considerably larger than others. From a strategic point of view it is important to know more about what land-use – transport associations applied in the large metropolitan areas as they grow more polycentric; as well as what apply in the more balanced polycentric regions that are often provincial regions.

A study of urban form and transport on Zealand/Capital Area analysed the center and subcenter structure of the region and showed how transport is correlated with regional centrality, sub-center access and several additional aspects of urban form – such as density, and access to public transportation. Centrality and subcenter effects on daily travel distances was compared with effects of centrality and subcenters on home values in the region. Surprisingly the centrality and subcenter effects on travel appear to be highly different from the ones that apply to home values. strengthening the case for form and location effects independent from housing-market sorting. Home values are also correlated with centrality and subcenter access but the relevant subcenters and the relative contribution from regional centrality and subcenter access to the effect differ from the location dependencies of transport. Locational effects on property values is mainly a regional centrality gradient and shows limited sensitivity to the variation in subcenter access across the region. The daily travel distances are substantially more sensitive to sub-center access across the region – in addition to regional centrality. Analysis indicate the access to subcenters and access to the regional center contribute equally to the explanation of daily travel distances, whereas access to the regional centre is ten times as important as subcenter access in the explanation of home values. Figure II.3.1 below present the urban form and location effects on daily travel distances home values on Zealand– indicating how daily travel distances depend on regional centrality as well as more local conditions such as population density and access to retail and service nodes.

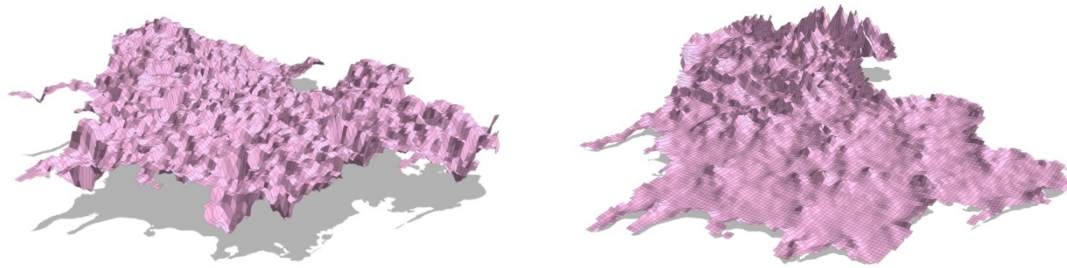


Figure II.3.1: Region of Zealand, Variation in location dependent daily km of travel (left) and home values (right). The maps are developed from partial correlations with location, urban form, infrastructure access, and environmental amenity variables. Maps present predicted values that are indexed to 0-100 for comparison (1 point on index equals 200 meter in base height).

The urban form and location correlations of travel do change over time and the evidence from the highly polycentric urban region of East Jutland documented a process where the distribution of commuting and population in the region over time grew more equal, dispersing regional commuting in a larger and more diverse space where especially the increase in commuting between remote origins and destinations pulls the average and aggregate travel demand up. Figure II.3.2 below present commuting and population distributions and trends in the region between 1982 and 2002.

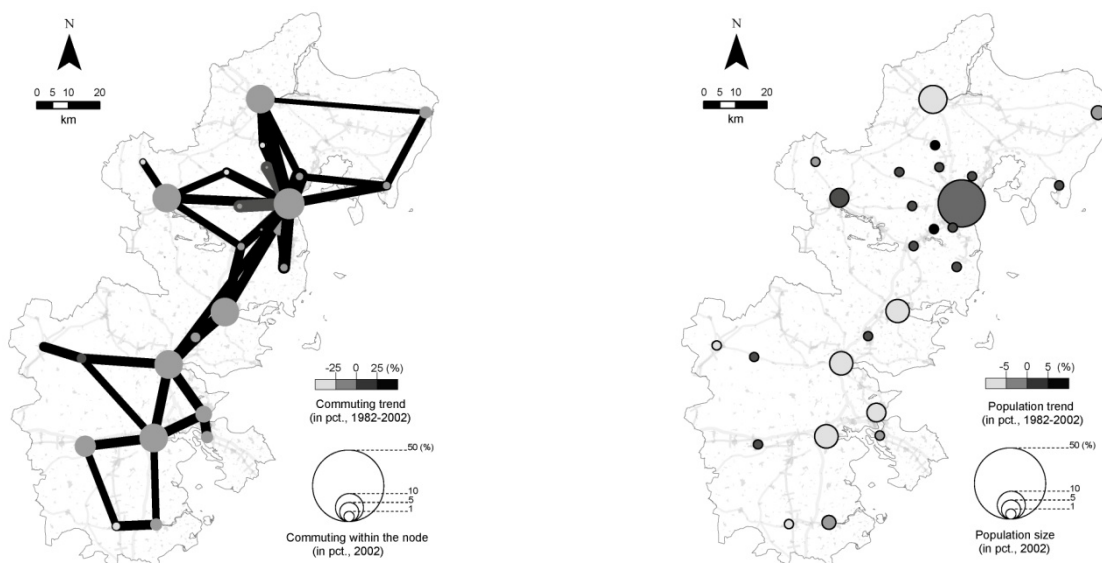


Figure II.3.2: Commuting within and between urban nodes (left); and population and development trend by urban nodes in the urban region East Jutland (right). Share of current commuting and population is indicated by the size of the signature and the growth trend between 1982 and 2002 is indicated by the colour.

As regions are developing due to land use change and changing interaction patterns the stability of location correlates of travel becomes an issue of strategical importance for urban management and spatial strategies supporting a sustainable development.

Analysis of changes through the 1990s in the location dependencies of commuting in East Jutland based on National Travel Survey data reflected a process of spatial up-scaling where the smallest urban centers in the region lost their significance over the period studied. Commuting distance in the region is related to the distance to the seven largest urban areas (six cities ranging from 40,000 to 60,000 inhabitants, and the larger city of Aarhus with 250000 inhabitants) as well as the wider set of 26 urban nodes. Proximity to a large city or one of the 26 cities implies a short commuting distance. This highlights the polycentric context of this provincial urban region: the relatively similar former market towns as well as a larger number of smaller nodes. The significance of the largest cities has been stable over time, whereas the significance of the smaller cities in the region is decreasing.

Reductions in the importance of access to public transportation in the determination of mode choice was also seen (Grunfelder and Nielsen, 2012). The findings suggest that the responsiveness to geography and location is becoming more critical in the sense that only very large concentrations of jobs and services seems to result in stable effects on travel behaviours. Such trends should be reflected in spatial strategies for sustainable urban development.

Parking

The study on parking departed from a panel dataset representing on-street parking that was made available by the City of Copenhagen. Parking as an area of research has been greatly neglected in transportation analysis as well as in data representations. The study on parking included in this project develops a stylized econometric model for the demand for on-street parking with focus on estimation of the elasticity of demand with respect to the full cost of parking. The full cost of parking consists of a parking fee and the cost of searching for a vacant parking space (cruising).. Demand elasticity for parking is highly relevant in the context of urban management if for instance parking policy is to be employed as a transport demand control measure regulating traffic volumes and congestion. The parking issue has been treated in the literature in the past but deserves further attention with respect to the effects of parking provision and pricing. Parking may be of more immediate importance to vehicle use than accessibility and urban form, and at the same time it interacts with these location attributes. Thus understanding parking will also be of general importance for the unfolding of land use –transport interactions. We demonstrate that parking fees can potentially be a useful policy instrument to organize the parking market and to reduce the external costs of traffic such as congestion (cruising), air pollution, and other relevant local environmental externalities. We also demonstrate that a spatially differentiated parking fee is necessary to induce the optimal parking pattern. Finally, the developed empirical methodology can be useful for the estimation of other similar reduced form demand equation describing the demand with the constrained capacity. Finally, the conducted study finds indications of a somewhat greater parking demand elasticity than is usually reported in the literature. This further highlights that parking policies can play an important role in urban management and urban transport regulation.

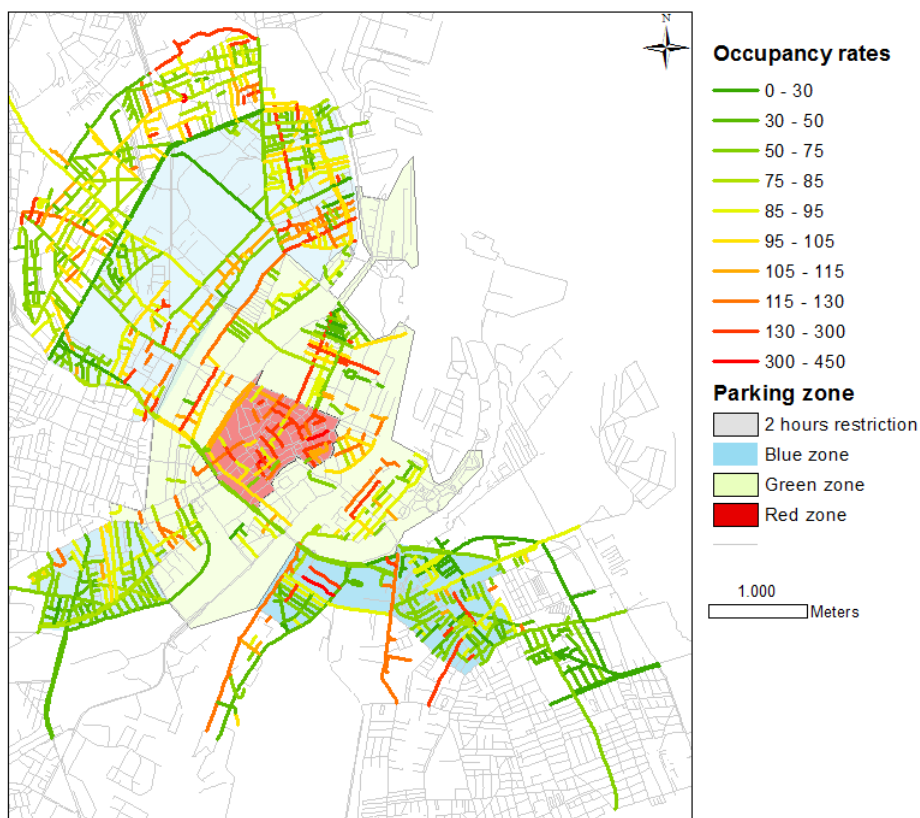


Figure II.3.3: Parking occupancy rates at noon (12:00) by street in central Copenhagen. Data is based on city officials' registrations in the field. The occupancy rate may exceed 100% as it is based on a comparison of the number of parked cars with the number of designated parking spaces.

Commuting distances effect on wages

The next study applied econometric methodology to examine individual-level compensating differentials for commuting distance in a quasi-natural experiment setting by examining how wages respond to changes in commuting distance induced by firm relocations. The continuous annual registration of commuting, employers and wages for all employees in Danish registers provides rare opportunities for semi-experimental isolation of exogenous induced shocks suitable for econometric analysis. It is well known that there is a positive correlation between commuting distance and wages, but few have looked into the direction of causality behind this correlation. The results indicate that 1 km of extra commuting distance is compensated with a 0.15% wage increase after 3 years (Mulalic et al., 2013). The estimated effect implies individual-level compensating differentials for commuting distance as predicted by labour market models that allow for job search frictions, and due to the quasi-natural experimental set-up excludes a range of other competing explanations frequently mentioned in the literature. Our findings are consistent with the notion that individual-level wage setting is an important characteristic of the Danish labour market. This study therefore implies that employers have market power and pay below workers' productivity, which is an important finding also internationally. There are a number of policy reasons why the effect of commuting costs on wages is of interest. For example, transport economists usually assume that employers do not compensate workers when road tolls are introduced, whereas our results suggest that employers will partially compensate workers for changes in commuting costs. This effect is, also, more fundamental and is related to la-

bour market theory. The evidence on the relationship between wages and commuting is informative about the relevance of labour market theories that assume the presence of job search frictions (including wage posting, bargaining and efficiency wage theory) which receive a lot of attention in the urban economics literature that analyses spatial aspects of markets. With this, it is of high relevance in describing the dynamics of cities and urban transport

Effects of new transport infrastructure

The final study also exploited the possibilities offered by Danish register data to analyze the effects of the Copenhagen metro as an exogenously induced change in accessibility. The research focused on the terminal metro station of Vestamager opening with the first phase of the metro in 2002; persons with residence in the chosen metro neighborhoods at the time when the new infrastructure was first operative (2002); and their changes in employment, earnings and commuting in the years following the opening of the metro line in 2002. The results indicated that metro access (proximity) affected commuting distances – but not uniformly for all. High earners, women, and older workers are more sensitive to good access to the new metro. An effect of a high grade, high speed infrastructure upon commuting distances is generally to be expected as commuting speeds can be increased. The interaction of the general effect with gender and income probably reflect contextual factors as the urban centre, to which the metro connects, may be more relevant for high income earners as well as to female workers - compared to the job offers in their local urban district (Amager). The effect of metro access on high earners is notably different than what is expected in the spatial-mismatch theory where public transport is seen as a possibility for poor people to connect to jobs. The Copenhagen case suggest that the metro opening provide opportunities for high-earners. The reasons for this very likely relate to the differences between the Northern European and the North American context where strong and old city centers, denser cities and higher level-of-service in public transport puts public transport in a different position.

II.3.3 Synthesis and Perspectives:

In addition to the research results presented in the previous section issues relating to methodology and the 'state' of the evidence base should be highlighted for their value in a general perspective. An important implication from studies in the area of urban form, land use and transport interaction is the problem of establishing causality in order to assess magnitudes of effects needed to compare effects between policy measures. Several of the studies indicate that attempting to establish causality is very difficult since causalities are, in all the cases observed, generally bi-directional in the short term. For instance residential location and the use of any particular mode of transport may be indicative of a response to transport preferences; however, in the longer term, where urban and transport infrastructure are provided in response to needs – then the physical attributes and available infrastructure may shape in turn future mobility needs and preferences. In relation to urban form and location the causality issue has been discussed at some length in connection to the topic of 'self-selection' and for infrastructure provision in connection to the phenomenon of 'induced demand' as the additional demand effect resulting from increasing provision of infrastructure beyond that which the infrastructure was aiming at servicing. The elaboration of the self-selection issue of (Cao et al., 2009) indicate the multiple causalities that could be relevant and the difficulty of arriving at an 'independent' or exogenous effect of urban form or infrastructure on transport behaviour.

However, since the more interesting results are about the effect of e.g. urban form on travel demand in order to be able to make policy recommendations, then it is necessary that the effect of the two variables considered are as close to being exogenous as possible. The literature is providing several partial solutions and explanations for different effects of interest, (e.g. use of statistical instrumental variables), but ideal conditions are difficult to achieve. There is a call in the literature for more longitudinal studies and more intervention studies to approach causal effects. The abundance of Danish register data as shown within this project, can take us some of the way and generally allow for comparable micro-data time series to support the analysis of any located infrastructure improvement or other event that can be linked to individuals based on public records. There is a large research and knowledge building potential for further use. The significant 'but' is that it mainly allows for analysis of issues such as labour market effects, wages, employment and commuting distances - whereas aspects of transport behaviour such as mode choice that is often targeted by transport policy is not part of the data. Targetting specific demand management features, such as parking provision and pricing, provides an additional challenge as these are site-specific and may be difficult to be (allowed) to match with micro-level register data. Thus analysis and policy prescriptions on transport behaviour must often rely on cross-sectional analysis of travel survey data or primary datasets which for very trivial reasons are often also limited to cross-sectional approaches.

For more descriptive analysis of the associations between urban form/location and travel demand/consumption one can of course relax on the aspirations towards causal inference and still produce new knowledge of interest to policy development. In general terms a multitude of urban form and location effects studies confirm general conclusions about the significance of urban form and location factors in transport and that these conclusions are robust towards methodologies and modelling approaches (Næss, 2006b) (Ewing and Cervero, 2010)(Nielsen et al., 2013). However, plausible magnitudes of effects that depend directly upon the causality/control issue cannot be formulated as a basis for e.g. cost-effectiveness analysis in the context of climate change mitigation or similar. The possibility of generalization to arrive at trustworthy magnitudes of effects on transport of for instance densification or urban containment strategies is of course contested. But this may cause a 'mismatch' to the transport planning and mitigation strategy development process where priorities are based on assessment of effects. How this problem is taken within a policy perspective is analysed in Part III of this report.

II.4 Freight Transport - the impacts of capacity utilization

II.4.1 Motivation

Demand for freight transport is derived from trade of goods at different locations including intermediate products that are needed for further production. The production of goods due to globalization is taken place more and more in a network of production sites. In Denmark this has meant that the import of heavy raw materials is growing more slowly while individual parts of the production process increasingly takes place where core competencies are most or most competitive; as a result there is a growing international division of labour and international freight transport of finished and unfinished products increases for ever-longer distances (Transportministeriet, 2010).

The goods at some point end in the retail sector leaving the very final transport to be made mostly by private transport using passenger cars. The way in which freight transport demand affects the total transport demand in the context of the current project, is in that the element or good being transported does not return to its origin, whereas the vehicle at some point returns to its origin, and when empty resulting in a less efficient vehicle utilisation.

The current research studies the transport being undertaken by heavy road vehicles nationwide in Denmark, which comprises almost 90 per cent of total freight traffic (Danmark Statistik, 2012). Overall the historical development in the traffic by trucks is driven by economic growth and a large increase in international transport couple with a smaller change in domestic freight traffic. That is because the drivers for these two are international trade and national trade respectively. And as is next discussed, they only to a minor extent influence each other.

An analysis of the main reasons for the observed and historical changes in domestic freight transport is made in (Kveiborg and Fosgerau, 2007). Their main finding is a slight decoupling of freight traffic (measured as vehicle kilometres) from economic development. The reason for this was found to be a large increase in the average load on the vehicles, but to some extent countered by an increase in the haul's length. They also documented how the main reason for the development in freight traffic (and freight transport) was economic development. Their analysis focussed on the period until 2002. Since 2002 the changes in GDP and freight transport and freight traffic have been much closer correlated though as it is indicated in Figure II.4.1.

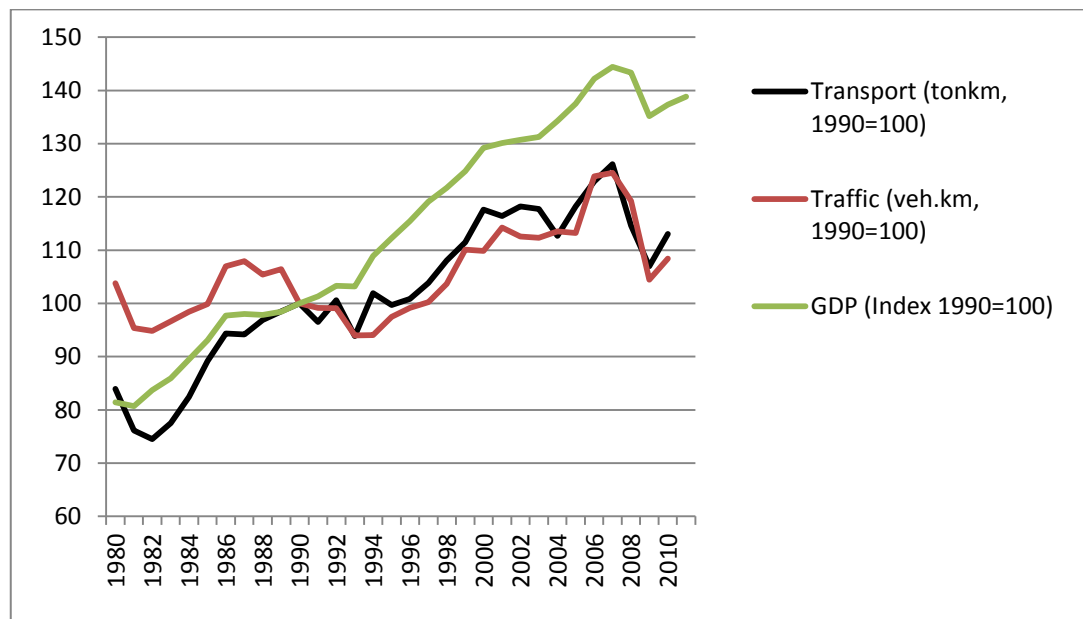


Figure II.4.1. Developments in freight traffic, freight transport and GDP. Index 1990=100

Similarly, there are constraints in the options available to the hauliers in choosing mode. In many cases there is only one option available as analysed by (Rich et al., 2011). This also influences the patterns on road freight transport.

A factor that often strikes decision makers and people looking into some of the problems caused by freight transport is the apparently low level of utilisation of vehicles. This is a problem not only for freight vehicles, but is also a problem found in individual use of passenger cars. Optimally this problem should be investigated in a context including all relevant factors and decisions. No doubt the overall objective for actors in freight transport is to minimise costs, but there are limitations to the possibilities of doing just that. Hence, the analyses in Drivers and Limits into one corner of the market – the carriers, can help us understand the relationships between general factors such as firm characteristics, vehicle types and sizes and possibilities for improving on the utilisation.

The present study takes a closer look at the average load of freight covering in fact two aspects; both related to the vehicle use and choice of vehicles. The two aspects are the matching of vehicles to the loads that must be moved and the use of the vehicles. The use of vehicles further includes both the actual loads relative to the potential load and the extent of vehicles driving without load.

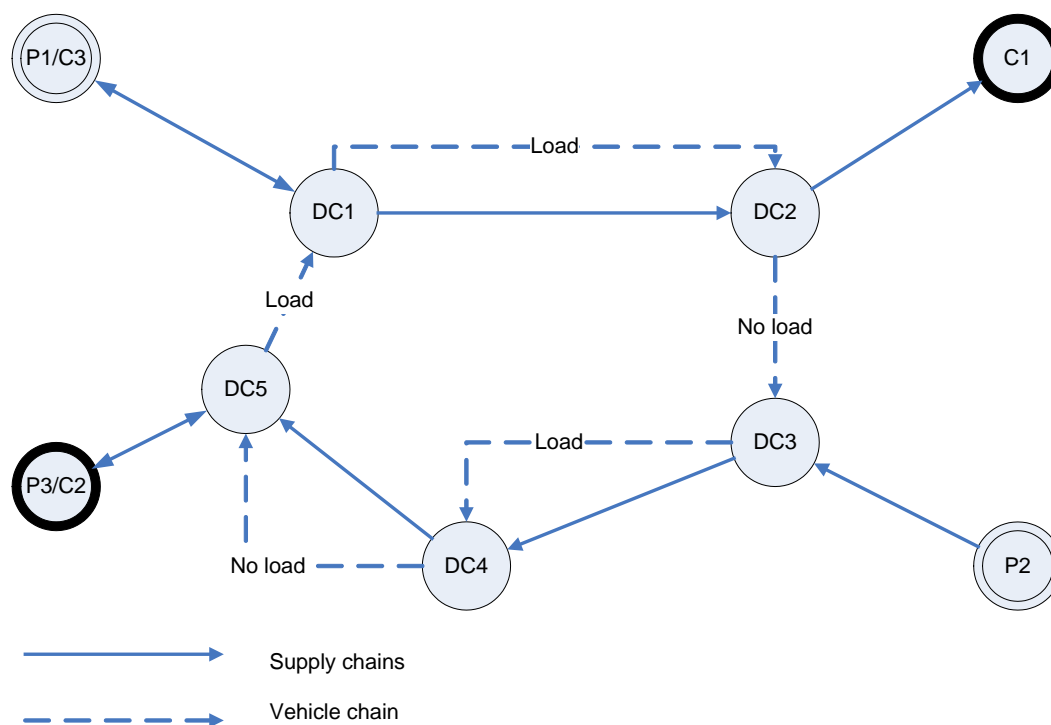


Figure II.4.2. Complex Trip Chains and The Related Supply Chains.

This is illustrated in Figure II.4.2. showing how vehicles run in complex patterns, where e.g. empty runs occur at several stages of its journey. To make it simple, we assume that all goods going from a production (P) to a consumption (C) pass through two distribution centres (DC), where the goods are consolidated and only truck is used. In the figure we consider three 'supply chains' one going from P1 to C1, another going from P2 to P3 and a third going from P3 to C3. The chain P1C1 passes through distribution centres DC1 and DC2, the chain P2C2 passes through DC3 and DC4, while the chain P3C3 passes through DC4 and DC1.

Each leg of the supply chains is performed by a distinct vehicle. However in the figure we follow a single truck in a trip chain starting in DC1 going to DC2 (loaded), from DC2 to DC3 (un loaded), from DC3 to DC4 (loaded), from DC4 to DC5 without load, and finally from DC5 to DC1 with load. The trip chain consists of 5 individual trips determined by separate supply chains and a trip back to the origin for the trip chain.

The reasons for the focus on these aspects are immediate. Any change in the utilisation of the vehicles either by an increasing load per vehicle trip or by reducing the extent of empty trips have a direct impact on the number of vehicle kilometres driven by heavy vehicles with a decreasing influence on climate and environment.

II.4.2 Results -Main findings

The vehicle utilisation is generally a result of an optimisation procedure made by the actors within the industry (shippers, forwarders and carriers), basically due to cost minimisation. The carriers are often assumed to be operating under perfect competitive conditions. Hence, it can thus be argued that costs are minimised and that it is not possible to change capacity utilisation. However, there may be circumstances that are not under the control of the individual carrier and there are constraints in the economy that prevents an optimal capacity utilisation.

Although it is recognised that there are these aspects, it is not directly possible to measure whether capacity utilisation is actually lower than some 'optimal' level. The optimal level seen from the individual carrier point of view is implemented. However, from a societal point of view the level may be less than optimal for different reasons. There are so-called externalities present. Individual carriers may not necessarily have all relevant information about loads, position of competitors' vehicles etc. Hence, only their own vehicles are included in the optimisation. The result is that the carrier accepts loads less than truck load. Another externality is that the individual carrier does not take the environmental impacts into account unless required to by e.g. taxes or other legislations. This is discussed in e.g. (Abate and Kveiborg, 2013) and can also be seen from Figure II.4.3, which illustrates four different accounts of capacity utilisation using the same data set. It is evident that care has to be taken in choosing which measure to use in the discussions of performance.

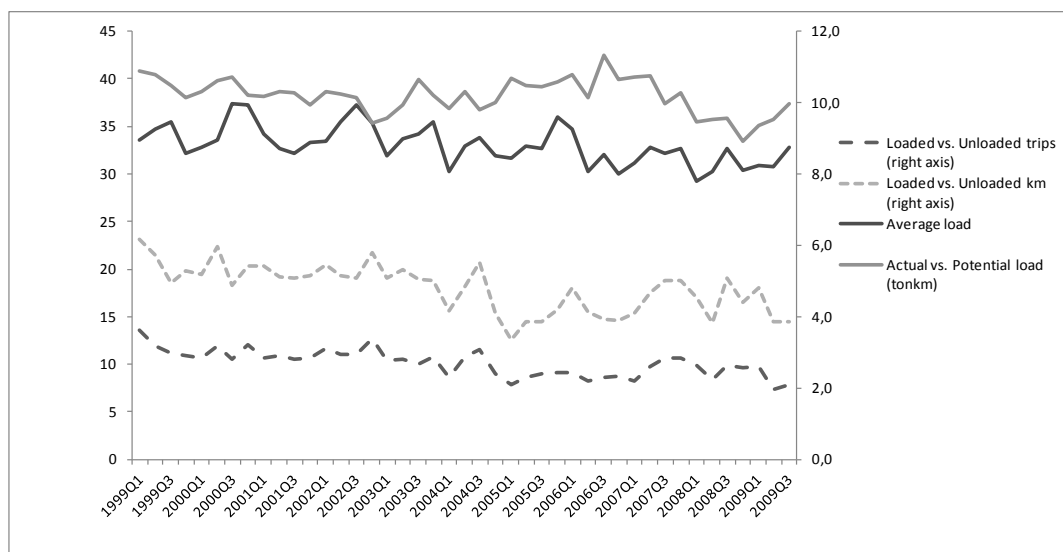


Figure II.4.3. Different measures of capacity utilisation on Danish freight transport each quarter from 1999 to 2009. Source: (Danmark Statistik, 2012), Vehicle diaries. Own calculations.

Even though the overall optimality is uncertain, it is important to understand the elements that influence the observed utilisation of vehicles. This is the objective of the present research work. Since, much of the choices are made by the carriers, the approach should use data about these firm choices. However, such data does not exist.

Freight transport data and data on logistic operations are rather limited. Freight transport is different from passenger transport due to the large number of decision makers: the shipper, who wants to ship a load from A to B, the forwarder(s) who are responsible for planning the necessary movements, consolidation etc. for the shipment, the carrier(s) who are responsible for moving the shipment and the receiver who is demanding the shipment. In passenger transport it is the same decision maker who decides on shipment and way of transport. The data sources for freight transport are spread across these different decision makers. There are a couple of international data sources that follow the shipments through the entire supply chain across the different decision makers; e.g. the French ECHO survey (Guilbault, 2008) and the Swedish and Norwegian commodity flow surveys (SIKA and SCB, 2005). However, even these data sources do not reveal the entire operation since many shipments are consolidated with other shipments on the same vehicles etc.

In contrast this study has had access to a data source on the operation of the carrier, which can be used to investigate some part of the problem related to the vehicle use. Many of the shipments are consolidated on the same vehicles and the carriers do make decisions on where to place their vehicles in order to maximise the use and earnings from the vehicle.

The objective of the analyses carried out is to learn which elements contribute to the changes and differences in vehicle utilisation. The size of the carrier firm is important. A firm with different types of vehicles will be able to have a better match between the size of the vehicle and the load that must be carried. However, it is very difficult to investigate this issue empirically due to the limitations in data. Although the firm can be identified and the size of the firm determined,

the data only reveal information about the specific use of one of the vehicles owned by this firm. Hence, it is not possible to directly relate the decisions made within a firm to the observed trips that are been made.

Instead focus has been on trying to gain insights in two other hypotheses.

The first hypothesis is that the carriers make a joint decision of which vehicle to use and the size of the load to be carried. This hypothesis is related to the decision made by a shipper/forwarder of a good, who simultaneously determine the size of the shipment and the mode of transport. This has been investigated using a adjusted version of the economic order quantity model, which determines when it is economically optimal for a firm to purchase new products taking into consideration transport and storage costs (Abate, forthcoming).

Results from the research carried out by (Abate, forthcoming) indicate that the main determinants of vehicle size choice are vehicle operating cost, vehicle age and carrier type. It is also shown that as operating cost increases the probability of choosing heavier vehicles increases, while higher total cost leads to a gradual shift towards smaller vehicles. Plots of the estimated choice probabilities are shown in Figure II.4.4 for total costs and in Figure II.4.4 for fuel costs. The figures only show rigid vehicles, but the results are similar when considering truck/trailer and articulated vehicles.

These seemingly contradicting effects of cost have important policy implications. For instance, in the face of policies or exogenous shocks which raise the variable cost of trucking operations (e.g. road pricing or fuel price rise) firms prefer to use heavier vehicles (Abate, 2014). On the other hand, policies or secular changes which increase fixed costs, and hence total cost, (e.g. registration tax, permits, licenses etc.), force firms to use smaller vehicles (Abate, forthcoming).

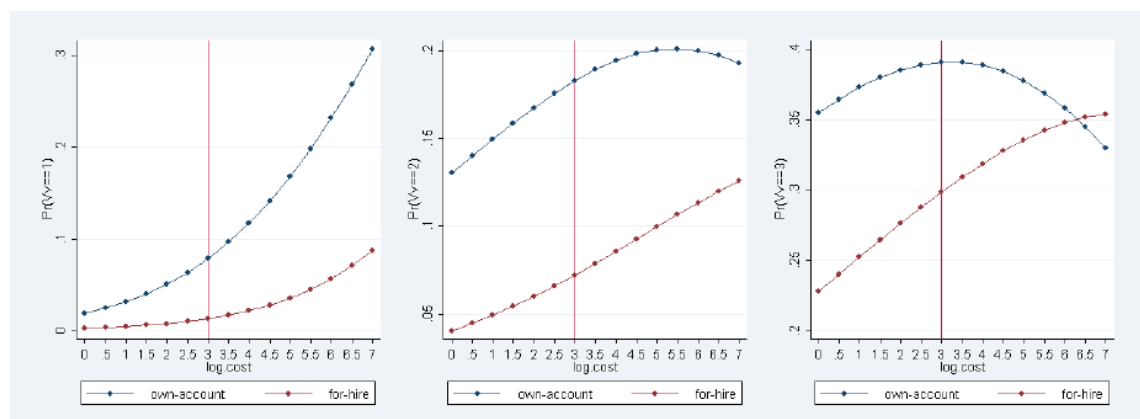


Figure II.4.4 Probability of choosing a truck size depending on total costs as proxy for variable costs. Rigid trucks (V1= gross weight < 12 tons, V2= gross weight 12-18 tons, V3= gross weight >18 tons)

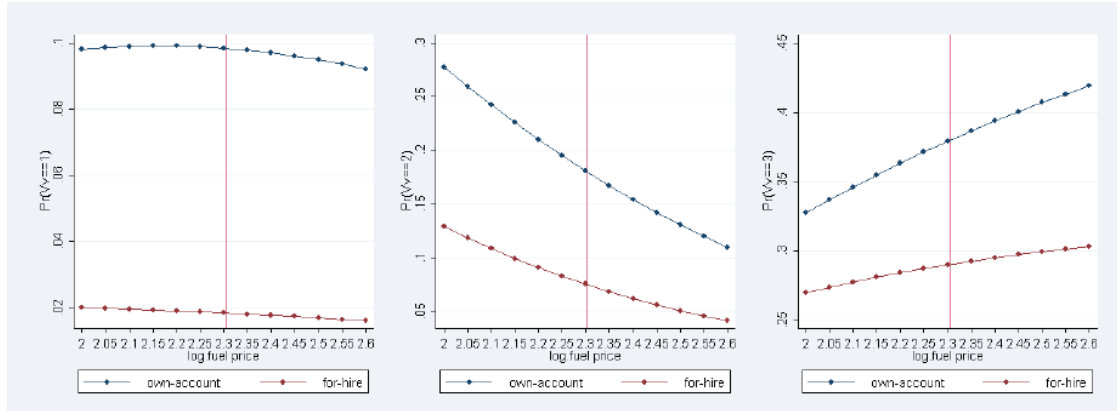


Figure II.4.4 Probability of choosing a truck size depending on fuel costs as proxy for variable costs. Rigid trucks (V1= gross weight < 12 tons, V2= gross weight 12-18 tons, V3= gross weight >18 tons)

The second hypothesis is that the decision of how much to carry on a vehicle is interrelated with the decision of carrying a load at all (empty running). The decision is influenced both by transport costs and especially the quantities of loads that can be picked up at the next destination.

This is investigated by Abate (2014) using a model where the load factor (LF_i) is given by the following equation:

$$LF_i = B_1X_1 + u_1$$

where

X_1 is a vector of explanatory variables and u_1 is a residual term. Observability of LF_i is conditional on the following market access equation (choice of carrying a load or not):

$$L_i = \begin{cases} 1 & \text{if } \delta_2X_2 + v_2 \geq 0 \\ 0 & \text{otherwise} \end{cases}$$

where

$L_i = 1$ if a truck is loaded; X_2 contains all variables in X_1 and additional variables for identification (exclusion restrictions); and v_2 is a residual term. X_2 is always observed, regardless of L_i .

The results (Abate, 2014) are obtained by jointly estimating the two equations and show that trip distance, truck size, fleet size and carrier type are the main determinants of capacity utilization. In particular, trucks on longer trips tend to have higher levels of load factor, and are more likely to be loaded.

This is shown in Figure II.4.5, where the average marginal effects on the probability of a truck being loaded are shown. The figure moreover shows that the size of the vehicle (measured by number of axles on the truck) is more responsive with respect to being loaded on longer trips compared to the age of the vehicle, where the increase in the probability of having a load is increasing at a slower pace.

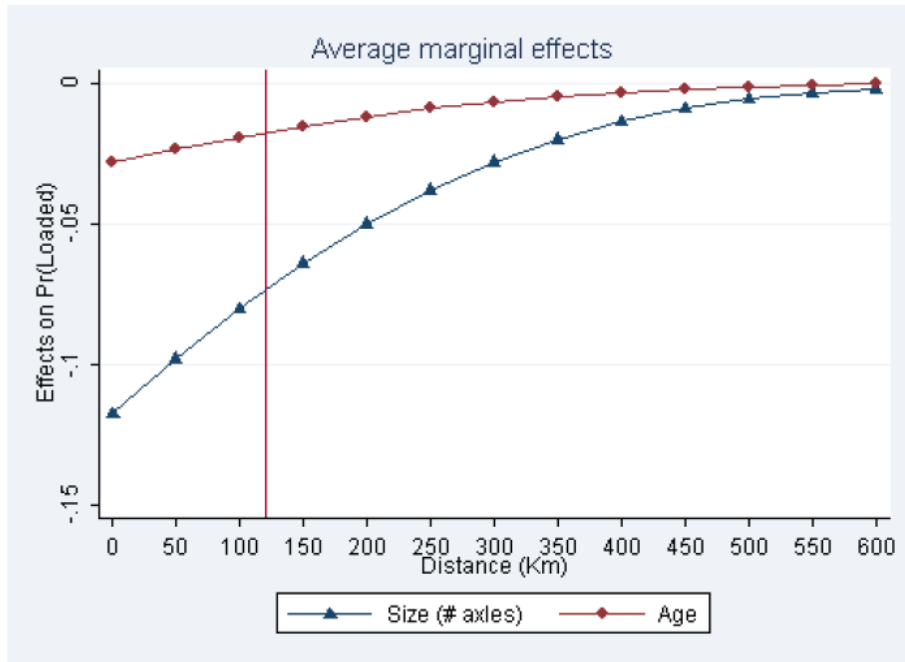


Figure II.4.5: Marginal effects of truck characteristics and distance

The analysis consistently shows that trucks owned by for-hire carriers are better utilized than those owned by own account shippers, which suggests that specialization in haulage service helps carriers to optimize resource use. But the effect of a trucks' size on utilization is not straightforward; while an increase in truck size contributes to excess capacity to some extent; its overall effect appears to be positive. These results are illustrated in Figure II.4.6.

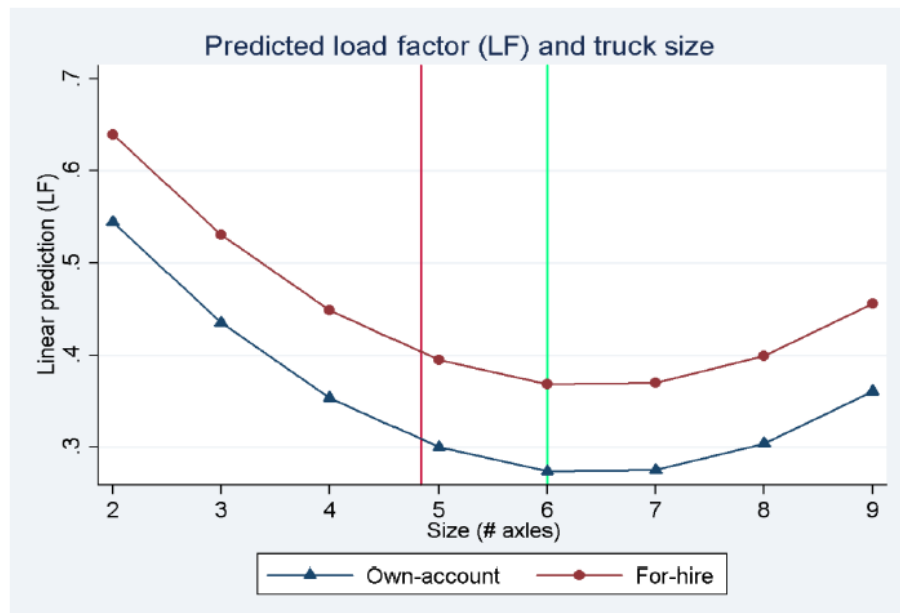


Figure II.4.6 Load factor and truck size

This result adds an interesting insight into the current policy debate in Europe regarding¹ whether increasing the maximum legal carrying capacity of trucks is beneficial or not.

A crucial limitation in the analyses is that they are focussing on only one decision maker in the supply chain as mentioned above. Hence, the decisions made by the carriers are made conditioned on the decisions made about shipment size and demand.

II.4.3 Synthesis and Perspectives

The analyses have indicated that efficiency in the freight transport sector can be improved by allowing larger vehicles and by encouraging the shift towards purchased transports. Although there are larger costs associated with carriers spending more time and resources in order to fill large vehicles compared to small vehicles, this is according to the findings here outweighed by a reduction in the necessary kilometres driven and moreover, when a large vehicle is used, then the costs of not using capacity is too large and hence, this induce carriers to increase the capacity utilisation.

The shift towards purchased transport has already happened to a large extent during the past decades. Now less than 20% of the trips and kilometres driven are for own account. The different industries have had focus on specialising in the activities that are their core business. Hence, several firms have outsourced the logistic operations to the trucking industry. The results support that this change will lead to further improvements in the utilization of these vehicles.

The pricing instrument (e.g. road taxes) is a further possibility to induce carriers to further seek optimisation. However, the results are ambiguous in this direction. Taxes directed towards fixed costs, such as annual vehicle taxes, will induce a shift towards smaller vehicles and thus a reduced average capacity utilisation, whereas changes in the variable costs such as e.g. road taxes will induce a shift towards large vehicles and thus also increasing capacity utilisation.

¹ See for example <http://libraryeuroparl.wordpress.com/2012/07/23/giga-liners-and-other-mega-trucks/>

PART III: Policy Perspectives

III.1 Purpose and content

The studies undertaken in the Drivers and Limits project provide new knowledge with potential relevance for different aspects of current transport policy and decision making in Denmark and possibly elsewhere as well. This section will discuss some possible policy implications of results that were summarised in Part II of the report.

This presentation is divided into the first subsection III.2 that seeks to place the research in a wider context of the contemporary transport policy landscape, and the second subsection III.3 that will address more specific policy related areas and interpretations corresponding to insights concerning the different 'drivers' reported in the above. Section III.4 offers a brief summary of this discussion.

III.2 The general transport policy landscape

III.2.1 reversing the growth in negative externalities

At the most general level the Drivers and Limits studies feed into a policy discourse on how to reverse future increases in negative external effects from transport systems and activities, and to what extent it is necessary and feasible to politically intervene in the generation and distribution of passenger and freight transport demand to pursue that objective. This is an ongoing debate in policy and academic literature across Europe and elsewhere (see e.g. ITF 2013; Moriarty and Honnery, 2013; Schoemaker et al 2012; Anable et al 2012; EC 2011, Kahn-Ribeiro et al 2007; Eddington, 2006), and also to some extent in Denmark as well (see e.g. Trængselskommissionen, 2013; Teknologirådet 2012; CONCITO 2013).

The main external effects that are considered here include the impact of CO₂ emissions on the global climate, and the congestion levels and time loss in urban areas due to increased concentration of population, economic activity and motorization. In addition impacts relating to traffic safety, air quality and noise are also important; together these form a set of challenges for achieving a more sustainable mobility situation. While climate change may be considered as the most serious problem overall, congestion is often seen to account for the largest share of the transport sectors' estimated external costs (Small and van Dender 2007; DØR 2014).

Clearly these externalities are already to some extent addressed in exiting policies, infrastructure planning and decision making in Denmark (Miljøministeriet 2013, Vad Mathiesen and Kappel 2013, Transportministeriet 2012). However it is widely perceived that already existing transport policies will not be sufficient or expedient enough to reach ambitious national goals for carbon independent transport (Regeringen 2013; Klimakommissionen 2010) and ultimately avoid the risk of dangerous interference with the global climate (Banister et al 2011; ITF 2008). The same has been said for existing measures to counteract mounting congestion and avoid increasing loss in welfare and economic performance in cities (Infrastrukturkommissionen 2008; Trængselskommissionen 2013).

For climate change a range of potential solutions involving more efficient technologies and alternative fuels may allow the bulk of needed reductions to be obtained (IEA 2012; ITF 2008, Klimakommissionen 2010), but it is still highly uncertain if such solutions will become available in time, and at sufficient quality, quantity, and pricing to reach the goals. Hence, interventions in transport activity and demand itself may be warranted at some point. Some form of intervention in transport flows is also required to reduce urban congestion, and such interventions may interfere with demand as well.

The most widely referred to measures for limiting excessive external costs of transport associated with CO₂ emissions as well as congestion are some forms of user pricing that reflects the associated external effects (DØRS 2014, Produktivitetskommissionen 2014). However, this is a politically controversial instrument that is clearly off the political agenda in Denmark for the time being, and difficult to implement on a European or international scale for international transport. There is therefore a strong interest in other possible solutions that involve regulation of transport activity and demand.

III.2.2 Risks of policy failure

While the need for urgent policy attention is widely recognized, there is also a real risk that stronger interventions in transport could be ineffective, or induce additional externalities without delivering comparable benefits (Ettema et al 2014; Banister 2012).

First and foremost restrictions on mobility would limit opportunities for travellers and businesses; this could detract from welfare and quality of life, build constraints for the operation of markets for housing, labour, goods and services, and undermine potential agglomeration advantages of urbanization. In the worst case too 'blunt' interventions could even reinforce the problems they were intended to alleviate (Moore et al 2010), like if driving restrictions induce travellers to make large detours or relocate their activities leading to net increase rather than decrease in total emissions. In other cases measures themselves may be so expensive to set up and operate in practice that any savings in external costs are undone (Eliasson 2009). The wish to avoid these types of policy failures is expressed in the European Commission's statement that 'curbing mobility is not an option' (European Commission 2011). Arguably, the need to stimulate rather than paralyse economic activity is currently placed at least as high on the policy agenda as eliminating externalities, and recent studies show that many policy makers directly shy away from suggesting coercive measures that could involve restrictions on individual choice, allegedly out of fear from such effects (Economides et al 2012).

A part of the solution may be measures to increase the efficiency of mobility services rather than 'curbing' them per se; that is, helping provide the potential for movement of passengers and goods that is needed, while reducing excessive physical movement of vehicles that is not needed. However, as for example shown in the literature study by Ecola & Wachs (2012) there is not sufficient knowledge to draw general conclusions about the relationship between transport demand (measured as VMT or VKT) and economic growth, and there is need for more research to specify how the two sides best can be decoupled from one another. Before we turn to interpret the results of the Drivers and Limits studies in this light we will first consider possible strategies to unlink externalities from mobility within the current transport policy agenda.

III.2.3. A widening policy agenda

Although there is significant variation in how national governments have embraced and defined transport policy the traditional approach has been strongly focussed on plans and investments to accommodate demand for transport, via extension, expansion and improvement to infrastructure (Goulden et al 2014, May et al 2006). Negative externalities affecting safety and environment have increasingly been recognized as part of this equation as well, but it was long believed that these could be minimized sufficiently by adopting technical standards for the system components (vehicles, fuels, infrastructure), and install moderate regulations of traffic behaviour (e.g. access to drivers licence, speed limits, blood alcohol limits, and associated enforcement).

Over the last two decades or so a gradual shift in this agenda can be observed in several countries; towards a broader and in some sense more ambitious approach (Perkins 2012; Himanen et al 2006). While the need for renewing and extending infrastructure clearly remains a top priority for policy makers (ITF 2013), these efforts are increasingly challenged by limited public funds, physical constraints, occasional public resistance, and the perceived scale and urgency of changes needed to fulfil goals for climate, quality of urban life, and other concerns.

The strategic scope for transport policy and the range of potential instruments under consideration has therefore been widened beyond simplistic 'predict-and-build' measures, towards also other solutions that can satisfy a broader range of objectives (ECMT 2005). Some see this as a genuine shift towards a 'sustainable transport' paradigm (e.g. Banister 2008), while others view it as a more gradual change in emphasis. In any case, policy makers are looking for ways to regulate transport demand, and to initiate innovations in mobility, transport and energy systems that will overcome serious external effects and risks at a more structural level than previously considered.

III.2.4. Strategies addressing external effects

Dalkmann and Branigan (2007; see also EEA 2010; Nakamura and Hayashi 2013) distinguishes between three types of strategies in this regard, namely to, '*avoid*' transport, meaning the elimination of the need for movement altogether '*shift*' car or air transport to lower emitting modes such as walking, cycling, rail, or public transport, '*improve*' the efficiency of the transport systems, either in terms of capacity utilization, energy efficiency, or carbon content of the fuels. After briefly introducing these strategies here the next section will discuss policy instruments that can be used to pursue each type of strategy.

In general, it is understood that the strategies to 'Avoid' transport are the most prophylactic ones and having potentially the widest range of effects across all externalities (UN DESA 2012; Høyer 1999), but they are also typically the most problematic ones to exploit and realise, due to the strong but intricate associations between transport demand and social and economic development, indicating a high risk of policy failures with weak or even negative effects (Banister 2012).

'Shift' strategies are regularly subscribed to by policy makers, as they often involve popular investments in public transport systems or cycling infrastructure that provide visible benefits to travellers (EUROBAROMETER 2013; Pridmore and Miola 2011; UNEP and FIA 2010). However, in reality this strategy is often limited with regard to the environmental benefits they can ac-

tually deliver, as significant shifts from for example car or air transport are difficult to achieve in practice (with some notable exceptions). This strategy may in practice *induce* as much as shift transport (Rietveld 2006). Most 'alternative' modes also themselves contribute to external effects.

Arguably the main emphasis has been on 'improve' strategies, prescribing or pushing for more advanced technologies for vehicles, fuels, infrastructures and communications (Kahn-Ribeiro et al 2007; ECMT 2006). Policy-led technical innovations have produced some of the most dramatic limitations to external effects so far (e.g. reduced air pollution due to clean vehicle equipment; reduced accidents due to better vehicle and road designs), and they also hold some of the most promising opportunities for the future (e.g. improvements to engine efficiency and, introduction of electric and hydrogen propulsion to mitigate CO₂ emissions). However, 'improve' strategies tend to address only one narrow set of problems at a time leaving others unchecked, and some of them also have inbuilt repercussions such as rebound effects due to fuel efficiency improvements (Maxwell et al 2011). Recent Danish experience for example suggest that substantial improvement to fuel efficiency of new cars may have been partly outweighed by increased sale and use of (small) cars (CONCITO 2013). Costs and safety are also major concerns. In correspondence with what was noted above, technology oriented 'improve' strategies are widely considered as essential, but are not necessarily sufficient to achieve climate goals. Hence combinations of 'avoid', 'shift' and 'improve' are likely to be needed if broad, ambitious policy goals are to be fulfilled (Givoni et al. 2013).

Still, the reduction of externalities needs to be seen as part of a wider transport policy agenda which concerns balancing the mitigation of externalities with the provision for access and mobility. Obviously there can still be scope for expanding transport infrastructure and transport services, for example in cases where mobility of value can be offered to society without producing significant externalities, or if such a provision can be demonstrated as the most effective option even to avoid additional externalities, for example to overcome excessive congestion, by eliminating bottlenecks in the system. In short, 'provide' strategies also retain a place in the policy agenda, even if they cannot stand alone, and they may also aim to provide mobility without necessarily extending the physical infrastructure.

III.2.5. Policy measures

Scholars have analysed which policy instruments can be deployed to pursue the different externality reducing strategies (see e.g. May 2013; Nakamura and Hayashi 2013, van Wee 2012; Banister et al 2012, EEA 2010, SoU 2013). The main types of measures generally include land-use planning, infrastructure investments, technological measures, regulations of transport markets and behaviour, economic incentives, and information.

Van Wee (2012) observes that 'regulations' and 'pricing' are measures that could be applied in pursuit of all the three 'externality' strategies, 'avoid', 'shift', 'improve', while the other instruments have relevance limited to 'avoid' and 'shift' strategies. Interestingly this suggests that there would be a broader set of instruments available for influencing demand compared to technology. Van Wee does not discuss the strength or the detailed mechanism in each area, nor any unintended effects on mobility or acceptability, but he advocates that measures should be

combined and assessed in comprehensive packages since it is difficult to target only one effect with each type of measures.

Nakamura and Hayashi (2013) make the similar observation that each type of instrument can support different strategies or even a combination of strategies. For example technology and infrastructure measures can support a combination of avoidance of car traffic and shifting to other modes, especially if also supported by land use control regulation. They illustrate, however, that the effective combinations of measures and strategies differ across regions in the world, depending on historic, economic and cultural context locally. For example, land use planning measures to 'avoid' transport and infrastructure investments to 'shift' it will have much larger potential for achieving CO₂ reductions in developing Asian cities than in more developed Europeans ones. In the latter, combinations of parking measures, road/fuel charges and reduced public transport fares may be more effective than expanding infrastructure that could induce further demand (Nakamura & Hayashi 2013, p 271).

May (2013) provides a qualitative ranking of the expected effectiveness of different measures with regard to different specific external effects. According to his review 'technology' (improve), and pricing and land use planning ('avoid' etc.) are the most effective with regard to reducing greenhouse gases, while less can be obtained by measures inducing 'shift' of modes. Congestion is most effectively addressed with pricing, although with possible roles for several other types of measures as well.

Banister et al (2011) present a more detailed review of a range of policy measure with regard to climate change specifically. This review suggest a potential role for a very wide range of measures, including pricing measures such as fuel taxation, tax incentives for low carbon fuels, a national congestion charge, but also non-economic measures such as fuel standards, car scrap-car schemes, promotion of carpooling, CO₂-labelling, campaigns, and other soft measures and even 'nudging' (Avineri 2012). For a few measures a quantitative estimate of reduction potential is offered, but for most it is noted that some effects are likely, while the context strongly affect the reduction potentials.

Other international studies (e.g. AEA 2011), as well as national studies in Denmark (Regeringen 2013, Teknologirådet 2012) have undertaken more specific assessment of reduction potentials for specific policy measures. It is clear even from those studies that existing estimates of effects are seen as uncertain, with regard to future technologies as well as the effectiveness of behavioural mechanisms.

Table III.1 suggests a simplified qualitative indication of the potential role of different instruments for the four strategies. The point is to illustrate that in principle there is a rich of array of policy measures that could influence the amount, split and efficiency of transport volumes. All of them offer some opportunities to drive a 'wedge' between the ultimately desired objectives (access and mobility) and the resulting externalities (climate impact and congestion), for example by offering proximity instead of physical transport, alternative travel options instead of car or truck use, more efficient utilization of the transport system, instead of more vehicle kilometres, or better mobility service or infrastructure, if the externalities are low. However each of these strategies also entail risks of producing unnecessary, costly or inefficient limitations on access,

mobility and well-being. In section III.3 this table will be used as reference to characterize insights from the analysis of drivers reported in the previous sections of the report.

Table III.1. Qualitative indication of the role of measures for strategies (adapted from May 2013; Banister et al 2011; AEA 2011). In practice obtainable effects will depend on context, measure strength, and packaging.

Strategies measures	Provide	Improve	Shift	Avoid
Investments	***	***	**	*
Regulation	*	***	*	**
Pricing	**	**	**	***
Information	*	*	*	*
Planning	*	*	*	**

III. 2.6 Types of Policy advice

Research knowledge can generally inform policy making processes in several ways, not only to identify the most appropriate instruments. How direct the relation can be depends on features on both sides of the research-policy divide. The type of research information can be distinguished in three broad categories (Boston 1994),

- ‘Operational’ policy advice relating to specific issues of policy implementation and the administration of government programs, including for example numerical adjustments to specific charges or regulation limits;
- ‘Strategic’ policy advice involving the production of researched, in-depth reports for political executives on various matters of public policy (e.g. concerning the role of the state as funder, provider, or regulator);;
- Independent social science research contributions, including studies on various topics of potential policy relevance, but not under control or direction of a particular policy agenda or demand.

The contributions from Drivers and Limits are clearly of the third type, and not intended for directly operational or strategic policy advice. It is still relevant to discuss possible policy implications, although these cannot be expected to be directly applicable.

Another important distinction concerns the kind of problems studied in the research (see figure III.1). Some research feed into an already well-structured body of knowledge, with high agreement over theories, methodologies, and empirical observations, producing results with relative certainty. Other research addresses more complex or ‘wicked’ problems, with a high degree of uncertainty and unpredictability (Hoppe 2010). Apart from the scientific uncertainty, the role of the research can also be affected by how controversial the problems are perceived to be, that is, whether there is normative or political disagreement over the goals, beyond what can factually established. The notion of ‘structured’ policy problems refers to both dimensions (Hoppe 2010).

In areas where theory and data allow to produce knowledge with high certainty and there is also broad normative agreement, it might be feasible to move from independent to strategic or even operational research, by improving research designs. In areas with less consensus, such a progression can be more difficult to achieve, and research results may even stir further controversies rather than consolidate a basis for action.

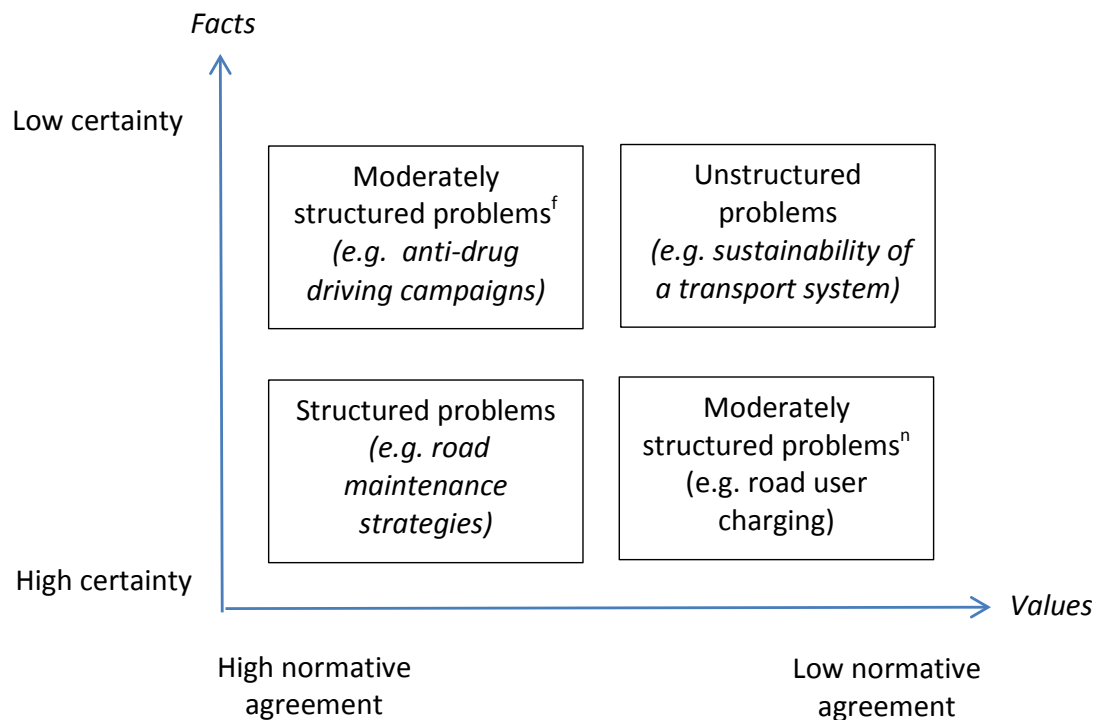


Figure III. 1. Research into different types of problem structures (adapted from Hoppe 2010; own examples).

III.2.7 The policy cycle

On the policy side there are also important distinctions as to what role research results can play. Policy making is an extended and sometimes disrupted processes moving through different states, where knowledge from research may be put to different functions along the way, apart from serving merely to supply factual knowledge supporting the selection of policy measures or projects.

A simplified policy cycle model is shown in Figure III.2

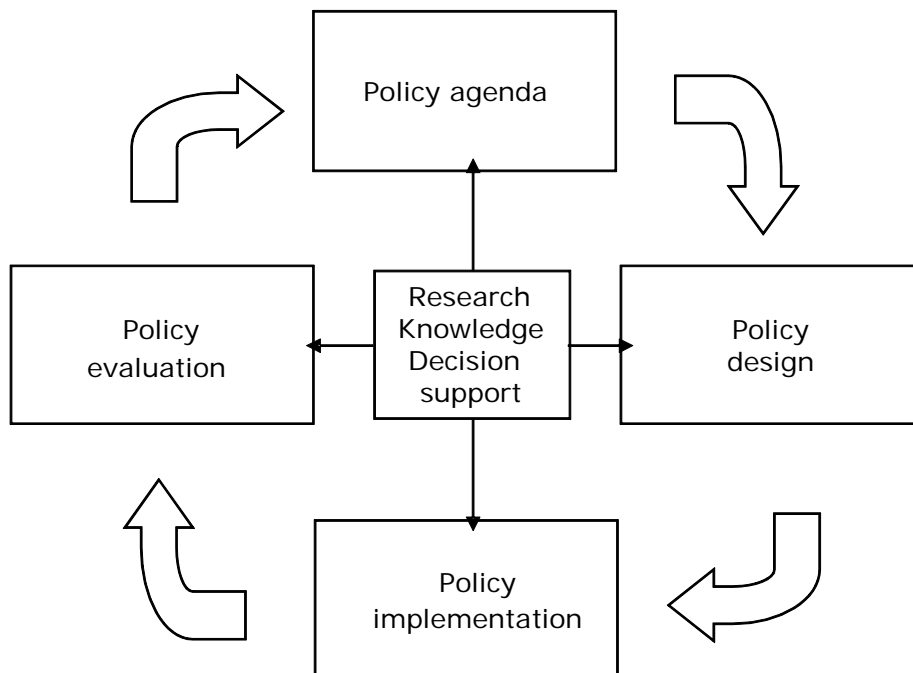


Figure III.2. Simplified policy cycle (Adapted from Giorgi and Tandon, 2003)

It is common to consider research relating to policy mostly as a question of improved *policy design*: the new research brings results that allow to specify and adopt policy measures, which will shape transport systems or steer transport behaviour to a desired results or in a desired direction. The research can provide a theoretical understanding of the part of the transport system being influenced, in support of a 'program theory' the decision makers assume (Johnson et al 2009); it sometimes establish 'dose-response' functions or elasticities between the policy measure and the object of regulation, which will allow a more specific calibration or fine-tuning of measures. The former fits with the notion of *strategic* advice, while the latter represents *operational* advice.

However, these functions assume that the problems are 'well structured' in the sense illustrated in Figure III.1. Some areas of transport policy may fulfil this condition to a high degree while others may not. The Drives and Limits studies have generally focussed on areas that are less well-structured from a policy point of view. They are all based on theories or assumptions about transport behaviour and system interactions, but not directly on 'program theories' addressing specific policy measures.

However, as indicated in figure III.2 there can be other relevant policy functions of research besides direct policy design support,

- The stage labelled as 'agenda setting' refers to a situation where issues are brought to the attention of policy makers and early steps towards structuration and possible interventions are considered. The research can help provide for example basic diagnostics about the problem, such as the magnitude of the problem, how it is evolving, what

seems to drive it, how its impacts are distributed across for example population groups or areas, or what knowledge is needed if policies are to be developed. The results are not necessarily linked to specific policy designs but can nevertheless be helpful to start a policy cycle. Due to issue complexity and ‘wickedness’ it may be necessary to conduct such exploratory research to identify more policy specific research needs. Some of the Drivers and Limits studies could well fit in here, as we will return to in the next section.

- The stage labelled ‘implementation’ is important in the sense that it involves transforming a ‘program theory’ into practice. In this process policies are likely to encounter various barriers or unforeseen effects, for example because of transaction costs or side effects from the policy instruments themselves (say, a charging system). This may also be due to possible conflicts with already existing policies in the same or related areas, or because the implementing agents may have a different understanding (or agenda) than the original policy makers had (Jann and Wegrich 2005). Research can here contribute to uncover and possibly mitigate such effects, for example by staging pilot projects or full scale experiments, or conduct accompanying studies during the implementation phase. The Drivers and Limits studies do generally not have this character.
- In the stage labelled ‘policy evaluation’ research can offer valuable input in regard to the understanding of how an existing policy has worked, both in terms of intended effects and in terms of possible unintended outcomes or side-effects. There are a range of models for undertaking direct evaluation studies, but here more independent research can also be valuable for example to identify casual mechanisms or interactions influencing policy outcomes, to undertake comparative research across different policy contexts, or to propose variables and indicators to use in ongoing monitoring or subsequent evaluation (Kusek and Rist, 2004). This is especially relevant if a policy or program is continued, renewed or otherwise enter into new policy cycles, even if the knowledge basis currently is limited. Some of the Drivers and Limits studies can also contribute in this phase.

The description of the policy cycle and the potential roles for research is obviously extremely simplified here. Policy making does not necessarily follow this clear sequence, and social science research is typically not in a position to apply isolated or experimental studies of individual specific policy interventions. The description mainly serves to underscore that research can nevertheless be of relevance for different dimensions in policy making, even if it is not in the form of operational policy design or specific evaluation studies. The last section in this chapter aims to illustrate this by relating selected findings from the Drives and Limits studies to ‘avoid’, ‘shift,’ ‘improve’ and ‘provide’ strategies, and the different types of policy application of research.

III.3 Discussion of specific policy topics

In this section some policy implications of results reported in section II will be discussed. For each area the current policy situation will be briefly reviewed, and some implications of the findings are proposed. Again it must be stressed that the purpose of the Drivers and Limits research has not been to conduct operational policy research. Most of the policy areas addressed

cannot be characterized as ‘well structured’, which means that there can also be divergent ways to interpret the implications.

III.3.1 Socio Economic and Demographic Factors

Policy relevance of the research

From a policy perspective it is important to understand if the behaviour of major population groups is likely to change in the future, for example towards more of differently mobile lifestyles with potential increases in emission and congestion, or the opposite. Will ageing of the population for example enhance or reduce the pressure on transport and environment? Will it require specific investments and adaptations to transport systems and infrastructure? Some countries are implementing specific transport policies to cope with aging populations (Mercado et al 2007), such as easier accessible public transport and more condensed urban structures in Japan where ageing is most advanced (MLIT 2009). Secondly it is relevant to consider how the different groups are likely to be responsive to policies to either avoid, shift or improve transport to limit externalities, and if such effects can be obtained without severe limitations to welfare achieved through mobility for these groups.

Summary of current policies

Current transport policy in Denmark is generally oriented towards accommodating expected increase in mobility and traffic, although constrained by environmental concerns and available funding, and targeted to areas with the strongest need (Transportministeriet 2009). Current predictions do not consider major changes in the socio-economic characteristics of the population. There is some, but limited diversification of transport policies with regard to age groups. Minimum age for driver's licence is 18. Elderly persons above the age of 70 are required to undergo regular medical checks to renew their drivers licence, for reasons of traffic safety. Measures to make public transport systems more accessible for elderly and disabled are continuously introduced. Retirees (above 65) can obtain significant fare reductions for public transport, even if it is regularly discussed if this option should be eliminated or replaced with general economic provisions. Young people can also obtain reduced fare cards ('Ungdomskort') to travel by public transport; these arrangements have been extended in recent years. Otherwise there is limited differentiation in transport regulations due to socio-economic or demographic characteristics. While there is broad support to underlying aims such as traffic safety and support to mobility, a policy of profiling mobility regulations for specific age groups is not highly structured, with limited evidence about effects, and occasional political debate about the existing measures. The research charts somewhat new territory in regard to Danish transport policy.

Interpretation of findings for policy

The Drivers and Limits research confirms that age, gender (and ageing society) does have an influence on actual travel demand, travel behaviour (e.g. tendency to drive a car) as well as expectations for future mobility. The 'ageing society' could contribute to limit future travel demand growth, since elderly people still tend to travel less than those in the active labour force. This tendency could potentially contribute to reduce the pressure on infrastructure and hence the need for transport demand limiting policies.

Coming generations of elderly will nevertheless likely expect a higher level of mobility to be available than some previous generation, and will be prone to associate high mobility with high

quality of life. Existing restrictions on elderly person's access to driver's licenses to some extent form a barrier for the mobility for this population group. Research suggests the elderly people without cognitive dysfunctions tend to compensate for reduced ability to drive, which questions the justification for the requirement to renew the licence (Siren and Meng 2013). By easing the procedure for renewing drivers licence valuable mobility could be provided for the population of elderly at low cost and with small added external effects.

The expectations among *young* people with regard to their future travel behaviour and mobility are diverse; it seems not likely that generational turnover in itself will lead to a falling demand for mobility. Some groups of young people no longer associate quality of life with car ownership, while others are more prone to do so. Policies to limit demand for car based travel could possibly be made more effective if they were targeted to motivated groups of young travellers. If there is a policy desire to avoid car travel that provides less value, there could be scope to explore especially which types of incentives would be effective for these groups to postpone driver's licence and car acquisition, since the perceived loss of value of mobility by not having access to a car could be limited; it could be particularly interesting to study how persistent any effects on mobility behaviour would be for the following life stages for the youngest generations.

III.3.2 Long Distance Travel

Policy relevance of the research

International travel is growing rapidly. According to the partial study air travel for Danes has increased by more than 7% per year over the period 2002-2012. Most of the growth is due to more frequent travelling, less is due to longer distances per trip. International air travel contributes a growing share of total emissions from Denmark, now around 16% of the transport sector total (Energistyrelsen 2012). Air space in Europe is also increasingly congested, and the problems could accelerate, as the number of flights is forecast to increase by 50% over the next 10-20 years (European Commission 2013). It is relevant to understand more about the background for the growth, to what extent it is likely to continue, and how the impacts could be reduced with policy measures.

Summary of current policies

With regard to international travel by air (as we will focus on here) the main policy has been to expand airports and associated infrastructure to allow travel to grow while also ensuring safety and security and some degree of environmental protection. Over the last 10-15 years a key policy effort at the European level has been to liberalize air travel, leading to dissolution of national monopolies, increased competition and lower prices. Until recently there were no policies addressing the CO₂ emissions from international air travel, but since early 2012, these have been included in the EU Emissions Trading System (EU ETS), where airlines must obtain partly tradeable emission allowances from the European Commission. Recently it has been agreed that a global trading system will be implemented in 2020 and meanwhile the EU has suspended part of the system for Non-European aviation. Increased congestion in European air space is tackled by the Single European Sky (SES) policy, including improved air traffic control, which is also intended to limit emissions as well. In some relation like Paris-London investments in high speed rail, has allowed to shift significant passenger volumes away from air transport. There are currently no policies in place to deliberately constrain the demand for international airline travel, even if ETS, and safety regulations may have some marginal effects in this regard. To introduce

such constraints would be highly controversial for business as well as leisure mobility and is currently not much discussed in Denmark (see e.g. Energistyrelsen 2013; Klimakommissionen 2010; although also Teknologirådet 2012).

Interpretation of findings for policy

The Drivers and Limits research shows that strong growth in international air travel from Denmark is observed for all income groups, regions, and for men as well as women; travel for those that already travel much is growing is less than for other groups, meaning that the difference in international travel is narrowing. Those that travel most are men, and people living in cities. The distance travelled annually increase with age of travellers but decrease after the age of 60. Aging population could therefore indicate that growth will slow down in the future, whereas increased urbanisation could point towards more international travel in the future, if new urban citizens will acquire the same patterns as the present ones.

The price reductions have followed a sharp increase in low-cost carriers and travel; hence some of the growth is due to competition induced by liberalization policy. However, the growth was found more to be due to increasing income than to lower prices.

There will likely be a strong continued increase in demand for international air travel; pressure to provide for demand, increase efficiency and limit emissions will all likely be further intensified. It will obviously require international coordination to limit the environmental and congestion impacts of air travel. The focus is predominantly on 'improve' measures, considering efficiency of engines and air traffic control, as well as the possibility to introduce second generation biofuels (ATAG 2012). This is an area where policies are not yet well structured. Better data to evaluate trends and assess the impact of policies are needed. Due to the international nature of the travel it would be especially sensible to undertake joint international travel survey data collection and analysis rather than only collecting national data. At the national level it would be highly interesting to analyse the relation between domestic and international travel for various age and population groups. In Sweden it is found that the overall growth in distance travelled abroad among the young generations exceeds a decline seen in long-distance mobility within the country (Frändberg and Vilhelmson 2014). To what extent is increased air travel for example associated with urban lifestyle and therefore potentially to be further enhanced?

III.3.3. Land Use and Urban Form

Policy relevance of the research

Land use and urban form have long lasting impacts on factors such as location choices, commuting patterns, travel distances and mode choice. Thereby land use also contributes to transport induced emissions and congestion. Many countries directly apply land use policy measures as part of strategies to limit CO₂ emissions, a prominent example being "compact city" strategies pursued by the Netherlands, Japan, and other countries as well as by the European Union (Banister 2012; Government of Japan 2008; van Wee 2002). Such policies in principle pursue 'avoid' as well as 'shift' strategies'. However, the interactions between transport and land use are highly complex and despite decades of research there are many unanswered questions, on how much transport demand and associated effects can actually be influenced by intervention in different spatial parameters such as density, diversity or design, and by using planning instruments such as zoning, investments, restrictions on development, densification,

and other measures. It is not obvious how to 'evaluate' planning policies that roll out over decades, while numerous other factors including self-selection will influence the decisions of individual and families regarding location and travel patterns.

A special case of 'land use' policy is parking regulations. By allocating or limiting space to parking it is possible to influence local traffic flows, but possibly also commuting and other travel patterns more generally. Parking policies include provision, restrictions, and pricing, all of which can be made variable with regard to space, time and user groups (e.g. residents, commuters etc.). Parking has attracted increasing attention as a policy measure in recent years (van Ommeren et al., 2009; Trængselskommissionen, 2013), not least when the use of direct road user charging is politically controversial. In this area policy evaluations may be more feasible than for land use strategies, although the effect on long term behavioural change may still be difficult to discern.

Summary of current policies

Denmark has a long standing tradition for integrated land use and transport planning. Most well known are the so-called 'finger plans' for the Copenhagen region, the most recent modification being adopted as a national planning directive in 2013 (Miljøministeriet 2013b). The objectives of the plan include the supply of adequate location opportunities for workplaces and dwellings, while limiting urban sprawl and greenfield development in the capital region. Location of major new office and other developments should be transit oriented, understood as located less than 600 m from a railway station.

The Danish Government recommend other cities to pursue broadly similar policies for central or transit oriented locations, although it is recognized that in many areas public transport cannot be a real alternative to the car (Miljøministeriet 2013a). In a project specifically for the Zealand area it was recommended to concentrate urban growth in the larger and most 'transport efficient' cities served by rail rather than allowing fully decentralised growth. However this was not elevated to a confirmed policy statement, in as much as allow degree of certainty as well as low political consensus create a rather unstructured policy situation, even if land-use planning as such has a long history, and is widely accepted. Some cities in Denmark themselves adopt 'compact city' and similar planning goals, but do not necessarily implements them in practice (see e.g. Næss et al 2013). Parking policies are mostly the domain of cities, although basic harmonized rule have recently been established. Copenhagen has the most extensive regulations including significant parking charges.

Interpretation of findings

The land use study focussed on travel in the polycentric regions of Zealand and Eastern Jutland. It was confirmed that travel patterns in Zealand are influenced by the centrality of locations in the region (attraction to Copenhagen) but also the presence of some more local sub-centres. The study in Eastern Jutland compared such influence in two different periods and found that the role of the more local sub-centres diminished with time. Hence it seems more likely that concentration of development near larger cities could affect travel, e.g. support shorter commutes. More comprehensive studies using panel data would be useful for providing stronger policy advice.

Another study showed that the Copenhagen metro may stimulate longer commutes by public transport. Such an effect was expected also for higher income groups who in some more car oriented countries would not be as sensitive to public transport provision. The results suggest that public transport investments - a 'provide strategy' - could have wider positive economic impacts by enlarging the labour market catchment area. The effect is likely to be dependent on the specific geographic context, where commuters primarily travel to a major urban center. To what extent such effects are relevant to incorporate in project assessments could be a topic for future research.

The study of parking in Copenhagen showed that parking charging may be used to reduce unnecessary driving (cruising) and hence eliminate emissions. Demand for parking is sensitive to prices, and the charges may be used more effectively to control traffic. It is largely an 'improve' strategy, to obtain a more efficient traffic flow. The study results could support an evaluation of the existing parking scheme in Copenhagen.

All in all these studies indicate the importance of spatial and infrastructure related factors for travel and commuting, but they do not point towards simple operational rules to follow in policy making regardless of context in time and space. Developing an evidence basis for policy will be an ongoing process where local factors must be taken into account.

III.3.4 Freight Transport - the impacts of capacity utilization

Policy relevance of the research

The growth in road freight transport has been a concern especially to the extent that it has been associated with a drop in capacity utilization and system efficiency. Heavy duty vehicles has assumed a growing share of transport emissions, with now around 25% of CO₂ emissions from road transport (Winther 2012). In urban areas trucks contribute to air pollution, congestion and risks. Around 30% of all freight has a final destination in cities (Energistyrelsen 2013). Freight transport is generally less well studied and understood from a policy point of view than passenger transport.

Summary of current policies

The capacity utilization of the vehicles is obviously not directly regulated but may be influenced by various existing policies. Road freight transport is affected by regulation at European, national and local levels. Trucks are covered by basic EU safety and environmental regulations with regard to vehicle size, technical design and performance, as well as maximum working hours for drivers. There are currently no limits for fuel efficiency or CO₂ emissions for trucks and generally no policy directly aiming to reduce CO₂ using either 'avoid', 'shift' or 'improve', strategies, apart from support to research and development. In Denmark trucks above 12 tons pay a road user fee (Vignette), and there are also charges to pass two major bridges. It has been decided several times to introduce a variable road user fee but these plans have been postponed and abandoned. On a pilot basis until 2017 the Danish government allows larger trucks (up to 25, meters; 60 ton), to operate in selected corridors of the national road network, with the purpose to enhance efficiency, competitiveness and environmental performance. The experiment is considered a success and will likely be made permanent in some form. Hence a range of European and national policies have been introduced in recent times in the trucking area, and it is likely that there will continued attention to the still rather unstructured policy field.

Copenhagen and three other Danish cities have an environmental zone prohibiting access of older polluting trucks above 3.5 tons; there is currently an experiment in city logistics in Copenhagen using a consolidation centre and less polluting vehicles for distribution to selected shops. The European Commission has set the general goal that there should 'essentially CO₂-free' freight distribution available in major urban centers by 2030.

Interpretation of findings

The freight transport study mainly addressed factors that influence the capacity utilization of trucks in Danish domestic transport. It was found that several policy related factors can affect the outcome in different ways, including the size and flexibility of the firm, and the extent to which freight is carried out as own account or for hire transport.

The research suggests that if hauliers have different types of vehicles at their disposal then increasing operating costs will lead towards the use of heavier vehicles for the jobs to be carried out if that while higher total (including fixed) cost leads to a gradual shift towards smaller vehicles.

Hence policy makers may be able to support a tendency to use larger trucks with a potential resulting improvement in efficiency if they for example would design future charges so they add to variable costs (e.g. road user tax; fuel tax) rather than fixed ones. The results also suggest that allowing larger trucks, as in the current Danish pilot experiment may also support improved efficiency.

The research does not provide operational guidance in these respects, but one possible implication for the policy agenda could be to extend the ongoing pilot to include collaboration with neighbour counties to allow of larger trucks also for international transport, where the efficiency gains may be higher.

The results do not identify the scope or scale for reduction on CO₂ emissions or congestion levels, but it plausible that a combination of increases in variable costs and opportunity to invest in large vehicles could contribute to positive results in both areas.

More than anything the study demonstrates the severe lack of publically available data of high quality for freight vehicles and commodity supply chains; an issue that is likely to become more problematic as transport volumes grow and their share of overall impact increase.

III.4 Summary of policy implications

Transport policy is undergoing significant changes these years in response to series of problems such as climate change, congestion and other externalities. While the provision of infrastructure to support access an mobility foe passengers and freight will likely remain a cornerstone in national planning and decision making, a broader range of policy options need to be considered, including strategies to potentially avoid, shift and improve the movement of vehicles transport to obtain significant end expedient results.

The Drivers and Limits studies do not provide direct operational policy recommendations for how to design and apply such strategies but offer insights of relevance for drafting of new policy agenda as well as for the implementation and evaluation of some existing policies.

In short it could be proposed first that mobility policies would be formulated with a more differentiated understanding of the needs of the various demographic groups, such as the elderly and the young generations; each population cohort is not necessarily adopting the same mobility patterns as the previous ones, and they may be sensitive to differently targeted strategies, taking into account specific life choices and flexibilities.

Secondly increased attention should clearly be offered to rapidly growing international transport, and how the demand is likely to be influenced by factors like aging, urbanisation and changes in 'ordinary daily travel'. There is a strong need for internationally coordinated data collection and analysis, for example in the context of the European Horizon 2020 programme.

Third it is clear that indicators and research with a longitudinal perspective allowing to better follow the impacts of land use and urban form changes over time need to be developed, and these should be applied in a way that will allow the specific spatial context for travel choices to be taken into account. The study on parking shows that there is at least a potential for applying travel demand management policies that could contribute to alleviate congestion and environmental impacts at the same time, without increasing the strain on public budgets and most likely will fewer controversies and acceptability issues than measures such as urban congestions charging

Finally it is clear that the area of freight transport and how it can contribute to reduce emissions while improving overall supply chain efficiency deserves more attention from a research as well as a policy perspective. Contradicting trends are at play, but there is reason to believe that factors like capacity utilisation could be affected by the use of economic incentives.

PART IV: Conclusions

Transport demand is a complex phenomenon driven by a host of different factors that jointly makes it difficult to provide well consolidated predictions of the far future, beyond the most aggregate level. Analysis that take into account spatial and socio-economic context is needed to be able to foresee the effects of measures to influence transport demand, in regard to factors such as distance, volume and modal split.

While there are few signs than the demand for mobility will fade away quickly, there are clear indications of a differentiated pattern, where some manifestations of mobility may become more prominent (e.g. international travel; more commuting in developed and polycentric regions; travel demand by certain groups of elderly such as former baby boomers), while other manifestations of mobility could under some circumstance become sensitive to policy measures that would seek to influence demand and limit physical volumes of traffic (e.g. lifestyles among groups in the young generation, searching for parking in cities; empty running of own account trucks).

One of the difficulties for conventional transport to influence demand is that the most important drivers of travel are external to transport. Drivers defined by demographic trends, average income, and the emergence of cultural trends in societies have significant impact on how much and where people travel; conversely transport developments may have played an undetermined role on the constitution of some of these drivers, for instance, among other developments in transport trends towards higher speeds, increased car ownership and increased public transport service availability are highlighted in the literature as elements at the core of definitions of a modern society. The built environment and land use distribution have a long term lasting effect on travel demand, however, a requirement that causality needs to be established to support policy recommendations is difficult to meet.

The approach of this study has been to seek understanding of the effects of drivers on travel demand while keeping in mind that limits are palpable and require due consideration and readiness to act, even if they are not absolute and objective.

Consideration of the limits makes apparent how the variety of forces unleashed by the drivers have a great variety of capacities to positively impact travel demand, while the potential effects of policy interventions are of more limited scope to affect the whole.. This study has contributed to advance understanding about some of the complexities involved. To summarize some of the key findings in the present study which lead in increased travel demand we found that in Denmark:

- Daily travel distances depend on regional centrality as well as more local conditions such as population density and access to retail and service nodes, this strengthen the case that urban form and location effects matter for transport demand and mobility patterns.

- Together with centrality still attracting most of the movement in Zealand, over time urban growth has reshaped the regional landscape into a connection of functionally integrated urban regions, with spatial separation between the nodes and a high degree of 'balance' in the East Jutland region this means that not a single city is highly dominant/considerably larger than others.
- This is partly a result of the distribution of commuting and population in the region over time growing more equal, dispersing regional commuting in a larger and more diverse space where especially the increase in commuting between remote origins and destinations pulls the average and aggregate travel demand up.
- The findings that increasing commuting distances are compensated economically by the employers could potentially be a factor that has played a role to incentivise the progressive dispersion of jobs.
- The overtime distribution of population into polycentric, functionally integrated and accessible but separated nodes can be paralleled with the trends observed amongst baby-boomers who significantly engage in daily car use while they are still working and with retirement become more active in their leisure time, potentially contributing as well to the overall increase in long distance travel. Still, the baby-boomers mileage is reduced with increasing age and after the initial years of retirement. Geographically, they are most likely to prefer living in subcenters with good accessibility to central places, which increases their dependency on car mobility to meet their travel needs.
- In contrast, parts of the younger population may still prefer centrality and the amenities that density, short distances, mixed use, and availability of public transport presents. Many report delaying decisions to use a car while still willing to obtain a license. They also express willingness to alternate between the car, the bicycle and public transportation while embracing new technological developments.
- Heterogeneity within population groups' demand for travel is a factor that plays a part. This applies to baby-boomers where differences between women and men are large and somewhat similar to those observed in other cohorts. Differences are substantial for instance in the frequency of international journeys which are highest for men; for individuals in the age group 41-60; for individuals with high income; and for individuals residing in the Greater Copenhagen area. The frequency of international travel in the general population even though is seen to increase with age it tends to decrease again after the age of 60.
- The increase in long distance travel is very high, the overall person kilometres made by Danes as air traffic has increased 80% over ten years making an increase rate of 7.2% per year in mean; there is no indication that this trend will significantly weaken, as long as major parts of the population have not reached the level of the most affluent male urban dwellers; there currently no policies applying to this trend other than possibly the conventional provide approach, but a need to set an agenda for policy making based on more comprehensive data.

- Finally, the trend towards polycentric regional forms interplays with the total distance for freight movements which has seen increases in the haul's length of trucks and the amount of empty running, all resulting in a less efficient vehicle utilisation. The analyses here indicated that efficiency in the freight transport sector can be improved by allowing larger vehicles and by encouraging the shift towards purchased transports inducing a reduction in the necessary kilometres driven and moreover, when a large vehicle is used, then the costs of not using capacity is too large and hence, this induce carriers to increase the capacity utilisation.

Considering the multiple ways in which the drivers impact travel demand, it becomes obvious that the limits to mobility presented by traffic congestion, budgetary constraints and climate change can always be addressed in the best way by keeping an exclusive focus on the provision of infrastructure and technological solutions. The concurrent examination of drivers and limits is useful as it helps bring focus to the question of what is scale of change required since reaching the limits of mobility by autonomous development is not ideal.

To reduce congestion may require implementation of certain number of individual policies, but achieving goals toward a full transition to a low carbon transport system will require a full integrated design of a package of policies and their sustained implementation.

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DTU Transport performs research and provides education on traffic and transport planning. It advises the Danish Ministry of Transport on infrastructure, economic appraisals, transport policy and road safety and collects data on the transport habits of the population. DTU Transport collaborates with companies on such topics as logistics, public transport and intelligent transport systems.

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